HANDBOOK

of

BIOLOGICAL DATA

Editor: SPECTOR

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HANDBOOK
of
BIOLOGICAL DATA

EDITED BY
WILLIAM S. SPECTOR

Prepared under the Direction of the Committee
on the Handbook of Biological Data
DIVISION OF BIOLOGY AND AGRICULTURE
THE NATIONAL ACADEMY OF SCIENCES
THE NATIONAL RESEARCH COUNCIL

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Foreword

Seven years ago the National Academy of Sciences-National Research Council contracted with the Wright Air Development Center, United States Air Force, to gather and compile for publication, in handbook form, basic established data in the biological and medical sciences. The principal objective of the Handbook, like that of similar volumes in the fields of engineering and physical sciences, is to serve the student, the teacher, and the expert who seeks information outside his own area of specialization. Another aim has been to produce as comprehensive a work as possible and, at the same time, keep it from becoming unwieldly in size and prohibitive in cost. To achieve this goal it has been necessary to condense some 20,000 sheets of data into the present number of tables, and, further, to condense each table to the point where only the most generally useful, informative, and comprehensive material would be included. Therefore, the data as presented are by no means complete, and the limitations of space and time have disallowed inclusion of many subjects of obvious importance.* Also, by the very nature of the subject material, certain of the tables will appear elementary to the expert in the field, while to the student — a beginner in the subject of the table — or to an expert in another field, the same data may seem extremely complex. For the compiler, who cannot possess an expert knowledge of all fields in the bio-sciences, the task of choosing for publication not only the subject areas, but also data within these areas, would have been utterly impossible without the unprecedented cooperation of some 17,000 biological scientists who gave freely of their time to serve as advisers, appraisers, contributors, and reviewers.

From the onset of the project, direction of the work was entrusted to the Committee on the Handbook of Biological Data, operating under the Division of Biology and Agriculture of the National Research Council. Membership of the Committee is representative of major fields in the biological sciences. The Committee, seeking the highest degree of authenticity, recognized that a specialist in a given field can best exercise the critical judgment necessary for evaluation of data in that field. He is also best able to identify those values derived from the most acceptable methods of measurement and those having the greatest likelihood, or actual history, of reproducibility in competent hands. The Committee accordingly prescribed that in selection and review of data, broadest collaboration be sought among outstanding investigators in each of the many areas of the biological sciences.

With the generous assistance of the Council's Office of Scientific Personnel, a "Panel of Appraisers," comprised of thousands of experts statistically proportioned into groups in relation to the various bio-science populations, was established to submit and grade table titles for inclusion in the Handbook and to suggest names of authorities to act as contributors. Each contributor to the Handbook was recommended by at least three experts in his field. Data received in the Handbook Office were compiled and reconciled into the Handbook format and resubmitted to the original contributors, as well as to a review panel — one panel for each table — for verification and authentication. By this procedure it has been possible to strip from the tables most of the questionable or borderline material, leaving for final presentation to the user only what is considered as fact or accepted as reliable theory by those who are competent to judge.

The tables in this Handbook represent the actual correlated contributions of more than 4,000 scientists and the counsel of an additional 13,000. In the face of this overwhelming response and devotion to the science, the compiler feels humble indeed.

The Handbook of Biological Data was prepared under USAF Contract No. 33(038)-2174 between the National Academy of Sciences and the Wright Air Development Center — to which funds were also contributed by the Department of the Army and the Department of the Navy — and Contract No. AT(49-1)-626 between the National Academy of Sciences and the Atomic Energy Commission. The first of the two contracts was administered under the direction of the Aero Medical Laboratory as Project 7158, Dr. J. W. Heim, Project Director, and the second, by Dr. John C. Bugher, former Director, Division of Biology and Medicine, Atomic Energy Commission.

Acknowledgment is made, on behalf of the Handbook Committee and the National Academy of Sciences-National Research Council, to Wright Air Development Center, Office of the Surgeon General of the Army, Office of Naval Research, and Division of Biology and Medicine of the Atomic Energy Commission, for the foresight and scientific judgment inherent in the commission to prepare this Handbook; to the scientists of the Smithsonian Institution for their most valuable assistance in problems of taxonomy; to the thousands of biologists all over the world who, as contributors and reviewers, made possible the completion of this edition; and to the thousands of others, unlisted, who so willingly responded to requests for advice. Acknowledgment is also made to the present and former members of the Handbook Staff for their loyalty to a most tedious and exacting task.

W. S. S.

*These, as well as more detailed coverage of areas in this Handbook, will be published in monographs dealing with such special fields as growth and reproduction, circulation and respiration, plant and animal physiology, biophysical and biochemical characteristics, and aquatic biology. Already in print are "Standard Values in Blood" (1952), "Standard Values in Nutrition and Metabolism" (1954), and Volume I of a five-volume "Handbook of Toxicology."

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Introduction

"Without generalization there is no meaning, and without concreteness there is no significance."

... A. N. Whitehead

This Handbook presents tabular data and certain graphs, charts, and diagrams in the broad general areas of plant, animal, and preclinical medical sciences. The guiding principle for inclusion of material was its basic importance or wide general interest, and its adaptability to tabular presentation. The fact that certain of the data may already have been compiled and published was not regarded as a reason for excluding them from the Handbook. Unfortunately, some fundamental material has had to be omitted, either because in condensing 20,000 sheets of data into some 500 pages certain subject areas suffered extreme curtailment, or because efforts to secure the needed information were unsuccessful, or because certain tables arrived in the Handbook office too late to allow the processing requisite to publication. Inability to publish material that a contributor may have spent hours in compiling is cause for deepest regret, and every attempt will be made to include it in a revision of this volume or in one of the specialized monographs.

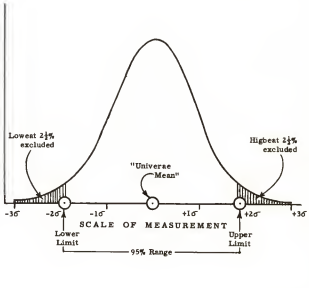
In considering presentational sequence of subject material, any one of a number of patterns could be followed. The one chosen appeared the most logical — first, chemical and physical data, then intra- or sub-cellular biology, followed by information on organs and organisms, growth and function, environmental effects, and, finally, distribution. The Table of Contents shows, for convenience of the user, a demarcation into ten categories. Within the book itself, however, no such clear-cut boundaries exist, and there is a gradual transition from one table or area to the next.

The chief objective in the preparation of this material in tabular form has been clarity of presentation. Where the subject matter of a table was considered to be inherently difficult for the non-specialist, effort has been made, in explanatory headnotes and footnotes, to resolve some of the difficulties. Certain of the tables contain symbols and terms peculiar to the fields of those tables. For each of these a glossary is included as an integral part of the table. In many instances information originally within the table itself has been moved into footnotes to simplify the structure of the table. Taxonomy, general definitions, symbols, and conversion factors, are covered in the Appendix.

One of the greatest difficulties encountered in the compilation of biological data is the element of variability. With few exceptions — and these clearly indicated — numerical values for variables are means, or adjusted means, of a group of measured values. To give these values significance, every effort has been made to present with the value an upper and lower estimate of the 95% range. The 95% range has been selected in preference to the standard deviation as better suited to the needs of the user who is not a specialist in the field from which a value has been drawn. The 95% range is a direct representation of the ordinary* range of variation, to be had only by further calculation if the standard deviation alone is available. The latter has the disadvantage of not being readily available, in many instances, and of giving biased limits for the 95% range when a variable has a skewed distribution. The statistically-minded reader who might wish to make further calculations from values in these tables may not care to proceed without facts on comparability and number of measurements. Unfortunately space does not permit including here such collateral information. Bibliographic references, available from the indicated contributor or from the Handbook Office, will lead to the original data where the desired material should be found.

The 95% range may be estimated in several ways, the method depending on the information available. The types of estimate most commonly encountered are listed below. The letter designations (a, b, c, d) will be found as superscripts identifying ranges given in the tables.** Range data as commonly encountered, including estimates of the 95% range, represent a mixture of the variability existing between individuals and the variability existing within individuals.

(a) By the method of greatest accuracy, the 95% range is obtained by fitting a recognized type of frequency curve to a group of measured values and excluding the extreme 2.5% of area under the curve at each end. (See sketch.) Estimate is made by this procedure only when the group of values is relatively large.



(b) By a less accurate method, the 95% range is estimated by a simple statistical calculation, assuming a normal distribution and using the standard deviation. This estimate is used when the group of values is too small for curve fitting, as is usually the case.

(c) A third and still less accurate procedure for gauging the 95% range is simply to take as range limits the highest value and lowest value of the reported sample group of measurements. It underestimates the 95% range for small samples (three or four values) and overestimates for larger sample sizes, but may be used in preference to the preceding method (b) when the sample shows convincing evidence that the variable is asymmetrical in distribution.

(d) The upper and lower limits of the ordinary range of variation, as estimated by an investigator experienced in measuring the quantity in question and based solely on general experience, constitute still another estimate of the 95% range. The reliability of limits so placed, although not as sound as with the methods listed above, should not be underestimated.

In some instances range data were not available; in others estimates of the 95% range are given, but information on the manner of estimate is lacking. Effort to assemble both types of missing information is continuing.

*To the clinician, equivalent, with reservations, to "normal and borderline."

**For details of these and other estimates the user is referred to standard texts on statistical methods.

QUESTIONNAIRE

TO THE USER OF

"THE HANDBOOK OF BIOLOGICAL DATA"

This volume is a first edition, comparable to first editions of other handbooks, particularly those in the physical sciences, in the sense that its initial presentation should offer a compilation not only useful in itself, but also one indicative of even greater service through improved future editions. Not yet subjected as a whole to the test of use and criticism by the scientific public, the book may be characterized by certain imbalances including areas treated too extensively or cursorily and remnant errors of commission or omission. We are convinced the persons best qualified to assist toward refined, superior future editions are those who, through study and use of this volume, have remarked such shortcomings. The following questions should receive particular attention by persons using this book. Your thoughts on them will be gratefully received at any time.

1. Has this first edition neglected to cover any general areas or specific tables, of fundamental usefulness to workers in the many biological sciences, that should be treated in a "handbook"?

2. Has it included areas not of this basic importance and utility, and of too specialized a nature for such a volume?

3. How might the coverage in certain areas, presently treated, be made more sound by expansion, contraction, or other types of revision?

4. Can gaps within specific tables be eliminated by incorporating material from the extant literature or from unpublished sources?

5. Are there typographical errors in any portion of the book, or definite errors of fact (i.e., values or statements you know to be untrue) that should be replaced in a revised edition?

If you are able to supplement your recommendations, we should appreciate receiving from you suggestions on sources of data needed for any revisions -- or preferably the data with references -- to modify, correct, or expand this initial presentation.

The Editor

2101 Constitution Avenue
Washington, D. C.

TABLES

Data in each of the following tables are, in the judgment of the contributors and reviewers, established fact or recognized theory, free of controversial material, and represent the consensus of expert judgment and experience in the special field from which the table is drawn. It is recognized, however, that all biological data are subject to continuing revision as investigators improve techniques and make more measurements. The user of this book is warned against attributing significance to small differences among species, or even within the same species while uniformity in methods of measurement is yet to be attained, and, particularly, where there may be marked differences in the size, age, or condition of the test samples.

Improper balance in coverage, despite the best efforts of thousands of advisors, may still persist, and many gaps remain to be filled. An appeal is made, particularly to the teacher and the specialist, to advise the compiler on the inclusion of important basic information that has been omitted, or on the deletion of material that may, for one reason or another, be considered as less useful to the student or non-specialist.

The user in general -- from the beginner to the expert -- is invited to submit any values or ranges he feels should be given consideration. It is hoped that such persons will participate in the development of a second edition with improved balance, better coverage, and elimination of errors.

1. STANDARD SOLUTIONS: pH_s

	Temp °C	HCl 0.1 M	Tetrox-salate[2]	Tart-rate[3]	Phtha-late[4]	Phos-phate[5]	Borax[6]
1	0	1.10	1.67		4.01	6.98	9.46
2	5	1.10	1.67		4.01	6.95	9.39
3	10	1.10	1.67		4.00	6.92	9.33
4	15	1.10	1.67		4.00	6.90	9.27
5	20	1.10	1.68		4.00	6.88	9.22
6	25	1.10	1.68	3.56	4.01	6.86	9.18
7	30	1.10	1.69	3.55	4.01	6.85	9.14
8	35	1.10	1.69	3.55	4.02	6.84	9.10
9	40	1.10	1.70	3.54	4.03	6.84	9.07
10	45	1.10	1.70	3.55	4.04	6.83	9.04
11	50	1.10	1.71	3.55	4.06	6.83	9.01
12	55	1.11	1.72	3.56	4.08	6.84	8.99
13	60	1.11	1.73	3.57	4.10	6.84	8.96
14	70	1.11		3.59	4.12	6.85	8.92
15	80	1.11		3.61	4.16	6.86	8.88
16	90	1.12			4.20	6.86	8.85
17	95	1.12			4.22	6.87	8.83

/1/ pH_s is defined as $-\log f_H m_H$, where f_H is the activity coefficient of hydrogen ion, and m_H is the concentration of hydrogen ion on the molal scale. /2/ 0.05M potassium tetroxalate. /3/ $KHC_4H_4O_6$, saturated solution at 25°C. /4/ 0.05M $KHC_8H_4O_4$. /5/ 0.025M KH_2PO_4 and 0.025M Na_2HPO_4. /6/ 0.01M.

2. ACID-BASE INDICATORS: pH RANGES

	Indicator[1]	pH Range	Acid Color	Alkaline Color
1	Thymol blue (acid range)	1.2-2.8	Red	Yellow
2	Tropeolin 00	1.3-3.2	Red	Yellow
3	Dimethyl yellow	2.9-4.0	Red	Yellow
4	Methyl orange	3.1-4.4	Red	Orange-yellow
5	Bromphenol blue	3.0-4.6	Yellow	Purple
6	Bromcresol green	3.8-5.4	Yellow	Blue
7	Methyl red	4.4-6.2	Red	Yellow
8	Bromthymol blue	6.0-7.6	Yellow	Blue
9	Phenol red	6.4-8.2	Yellow	Red
10	Neutral red	6.8-8.0	Red	Yellow
11	Thymol blue (alk. range)	8.0-9.6	Yellow	Blue
12	Phenolphthalein	8.0-9.8	Colorless	Red-violet
13	Thymolphthalein	9.3-10.5	Colorless	Blue
14	Alizarin yellow	10.1-11.1	Yellow	Lilac
15	Nitramine	10.8-12.8	Colorless	Orange-brown
16	Tropeolin 0	11.1-12.7	Yellow	Orange-brown
17	Trinitrobenzoic acid	12.0-13.4	Colorless	Orange-red

/1/ A solution containing 0.1 percent indicator is satisfactory. Water is a suitable solvent for all the indicators listed except dimethyl yellow, neutral red, phenolphthalein, thymolphthalein, and nitramine; 70 - 90% ethanol should be used to dissolve these indicators.

3. BUFFER SOLUTIONS: pH RANGES

	Acidic Component	Alkalioc Component	pH Range
1	Hydrochloric acid	Glycine	1.0-3.7
2	Hydrochloric acid	Potassium hydrogen phthalate	2.2-4.0
3	Citric acid	Disodium hydrogeo phosphate	2.2-8.0
4	Acetic acid	Sodium acetate	3.7-5.6
5	Potassium hydrogen phthalate	Sodium hydroxide	4.0-6.2
6	Potassium dihydrogen phosphate	Sodium hydroxide	5.8-8.0
7	Boric acid	Borax	6.8-9.2
8	Diethybarbituric acid	Sodium diethylbarbiturate	7.0-9.2
9	Hydrochloric acid	Borax	7.6-9.2
10	Glycine	Sodium hydroxide	8.2-10.1
11	Borax	Sodium hydroxide	9.2-11.0
12	Disodium hydrogen phosphate	Sodium hydroxide	11.0-12.0

4. OXIDATION-REDUCTION (REDOX) POTENTIALS

E_o at pH 7.0 and 300 C.

	Indicator	E_o (volts)
1	(Standard oxygen electrode)	+0.810
2	Phenol-o-sulfonate-indo-2,6-dichlorophenol	0.273
3	m-Bromphenol indophenol	0.248
4	o-Bromphenol indophenol	0.230
5	Phenol indophenol	0.227
6	Phenol blue	0.224
7	2,6-Dibromphenol indophenol	0.218
8	m-Cresol indophenol	0.208
9	o-Cresol indophenol	0.191
10	Thymol indophenol	0.174
11	2,6-Dibromphenol indoguiol	0.159
12	1-Naphthol-2-sulfonate indophenol	0.123
13	Tolupholine blue	0.115
14	Thionine (Lauth's violet)	0.063
15	Brilliant cresyl blue	0.047
16	Gallocyanine	0.021
17	Methylene blue	0.011
18	Janus green (a)	-0.011
19	Ciba scarlet sulfonate	-0.036
20	Pyocyanine	-0.040
21	Indigo tetrasulfonate	-0.046
22	Methyl capri blue	-0.060
23	Indigo trisulfonate	-0.081
24	Nile blue	-0.122
25	Gallophenine	-0.142
26	Brilliant alizarine blue	-0.173
27	Phenosafranine	-0.252
28	Dimethyl phenosafranine	-0.260
29	Tetramethyl phenosafranine	-0.273
30	Safranine T	-0.289
31	Neutral red	-0.325
32	Viologens	-0.400
33	(Standard hydrogen electrode)	-0.421

5. ORGANIC SYSTEMS: NORMAL OXIDATION-REDUCTION POTENTIALS

	System	Potential E'_o, volts	pH
1	Epinephrine	0.808	0.0
2	Cytochrome a	0.29	7.4
3	Cytochrome c	0.26	5-8
4	Cytochrome b	- 0.04	7.4
5	Reductone	0.282	0.0
6	2,6-Dichloroindophenol	0.217	7.0
7	Hemoglobin	0.152	7.0
8	Ascorbic acid	0.136	4.59
9	Methylene blue	0.011	7.0
10	Succinate-fumarate	- 0.015	6.7
11	Pyocyanine	- 0.034	7.0
12	Flavoprotein (yellow enzyme)	- 0.059	7.0
13	Alcohol-acetaldehyde	- 0.090	7.45
14	Hemin	- 0.114	6.99
15	Lactate-pyruvate	- 0.186	7.01
16	Riboflavin	- 0.208	7.0
17	Pathiocol	- 0.208	7.32
18	Cystine-cysteine	- 0.227	7.15
19	Glutathione	- 0.233	7.15
20	Coenzyme I	- 0.325	7.4

/1/ Symbol used for systems in which H^+ ions are involved.

6. IONIC SYSTEMS: NORMAL OXIDATION-REDUCTION POTENTIALS AT 25°C

	Oxidation-Reduction System	Electrode Reaction	Normal Potential E_o, volts
1	$Co^{++} \rightleftharpoons Co^{+++} + e$	$Co^{++} \rightleftharpoons Co^{+++} + e$	1.817
2	$Ce^{+++} \rightleftharpoons Ce^{++++} + e$	$Ce^{+++} \rightleftharpoons Ce^{++++} + e$	1.55
3	$Cl^- \rightleftharpoons Cl^-$	$Cl^- \rightleftharpoons \frac{1}{2} Cl_2 + e$	1.3583
4	$Sn^{++} \rightleftharpoons Sn^{++++} + 2e$	$Sn^{++} \rightleftharpoons Sn^{++++} + 2e$	1.256
5	$Tl^{++} \rightleftharpoons Tl^+$	$Tl^+ \rightleftharpoons Tl^{+++} + 2e$	1.211
6	$Br_2 \rightleftharpoons Br^-$	$Br^- \rightleftharpoons \frac{1}{2} Br_2 + e$	1.0648
7	$Hg_2^{++} \rightleftharpoons Hg^{++}$	$\frac{1}{2} Hg_2^{++} \rightleftharpoons Hg^{++} + e$	0.9011
8	O_2 (1 atm.) $\rightleftharpoons OH^-$ at pH 7	$OH^- \rightleftharpoons \frac{1}{4} H_2O + 1/4\, O_2 + e$	0.810
9	$Fe^{++} \rightleftharpoons Fe^{+++}$	$Fe^{++} \rightleftharpoons Fe^{+++} + e$	0.7477
10	$MnO_4^- \rightleftharpoons MnO_4^=$	$MnO_4^- \rightleftharpoons MnO_4^= + e$	0.564
11	$I^- \rightleftharpoons I^-$	$I^- \rightleftharpoons \frac{1}{2} I_2 + e$	0.5345
12	$Cu^+ \rightleftharpoons Cu^{++}$	$Cu^+ \rightleftharpoons Cu^{++} + e$	0.455
13	$Tl^{+++} \rightleftharpoons Tl^{++}$	$Tl^{++} \rightleftharpoons Tl^{+++} + e$	0.37
14	H_2 (1 atm.) $\rightleftharpoons H^+$	$\frac{1}{2} H_2 \rightleftharpoons H^+ + e$	0.0000
15	$HCN + H_2O \rightleftharpoons HCNO + H^+$	$HCN + H_2O \rightleftharpoons HCNO + 2H^+ + 2e$	0.0
16	$Pb \rightleftharpoons Pb^{++}$	$Pb \rightleftharpoons Pb^{++} + 2e$	- 0.126
17	$Mn \rightleftharpoons Mn^{++}$	$Mn \rightleftharpoons Mn^{++} + 2e$	- 1.1
18	$Al \rightleftharpoons Al^{+++}$	$Al \rightleftharpoons Al^{+++} + 3e$	- 1.7
19	$Mg \rightleftharpoons Mg^{++}$	$Mg \rightleftharpoons Mg^{++} + 2e$	- 2.4
20	$K \rightleftharpoons K^+$	$K \rightleftharpoons K^+ + e$	- 2.924

/1/ Reference electrode.

7. ACIDS AND BASES: DISSOCIATION CONSTANTS

Values are for determinations at 25°C, unless otherwise indicated.

	Acids				Bases			
	Acid	Formula	Constant for 1st Hydrogen	Constant for 2nd Hydrogen	Base	Formula	Constant for 1st Hydroxyl	Constant for 2nd Hydroxyl
1	Acetic	$C_2H_4O_2$	1.75×10^{-5}		Acetamide	C_2H_5ON	3.1×10^{-15}	
2	α-Alanine	$C_3H_7O_2N$	9×10^{-10}		Acetanilide[3]	C_8H_9ON	4.1×10^{-14}	
3	Arsenic	H_3AsO_4	5×10^{-3}	4×10^{-5}	α-Alanine	$C_3H_7O_2N$	5.1×10^{-12}	
				6×10^{-10} (3H)	o-Aminobenzoic	$C_7H_7O_2N$	1.4×10^{-12}	
4	Arsenious	$HAsO_2$	6×10^{-10}		Ammonium hydroxide	NH_4OH	1.8×10^{-5}	
5	Barbituric	$C_4H_4O_3N_2$	1.05×10^{-4}		Aniline	C_6H_7N	4.6×10^{-10}	
6	Benzoic	$C_7H_6O_2$	6.3×10^{-5}		Arsenious oxide	As_2O_3	1×10^{-14}	
7	Boric	H_3BO_3	6.4×10^{-10}		Beryllium hydroxide	$Be(OH)_2$		5×10^{-11}
8	Bromacetic	$C_2H_3O_2Br$	1.38×10^{-3}		Brucine	$C_{23}H_{26}O_4N_2$	7.2×10^{-6}	2.5×10^{-11}
9	Butyric	$C_4H_8O_2$	1.48×10^{-5}		Butylamine, sec.	$C_4H_{11}N$	4.4×10^{-4}	
10	Carbonic[1]	H_2CO_3	3.5×10^{-7}	4.4×10^{-11}	Caffeine[4]	$C_8H_{10}O_2N_4$	4.1×10^{-14}	
11	Chloracetic	$C_2H_3O_2Cl$	1.4×10^{-3}		Cinchonine[4]	$C_{19}H_{22}ON_2$	1.6×10^{-7}	3.3×10^{-10}
12	Citric	$C_6H_8O_7$	8.4×10^{-4}	1.8×10^{-5}	Cocaine	$C_{17}H_{21}O_4N$	4×10^{-7}	
				4×10^{-6} (3H)	Diethylbenzylamioe	$C_{11}H_{17}N$	3.6×10^{-5}	
13	Dichloracetic	$C_2H_2O_2Cl_2$	5×10^{-2}		Diethylamine	$C_4H_{11}N$	1.26×10^{-3}	
14	Formic	CH_2O_2	1.76×10^{-4}		Diisoamylamine	$C_{10}H_{23}N$	9.6×10^{-4}	
15	Fumaric	$C_4H_4O_4$	1×10^{-3}	3×10^{-5}	Diisobutylamine	$C_8H_{19}N$	4.8×10^{-4}	
16	Hippuric	$C_9H_9O_3N$	2.3×10^{-4}		Dimethylamine	C_2H_7N	5.2×10^{-4}	
17	Hydrocyanic	CHN	7.2×10^{-10}		Dimethylbenzylamine	$C_9H_{13}N$	1.05×10^{-5}	
18	Hydroquinone[1]	$C_6H_6O_2$	1.1×10^{-12}		Dipropylamine	$C_6H_{15}N$	1.02×10^{-3}	
19	Hydrosulfuric[1]	H_2S	9.1×10^{-8}	1.2×10^{-15}	Ethylamine	C_2H_7N	5.6×10^{-4}	
20	Hydrazoic	HN_3	1.9×10^{-5}		Ethylenediamine	$C_2H_8N_2$	8.5×10^{-5}	
21	Hypochlorous[2]	HOCl	3.7×10^{-8}		Hydrazine	$N_2H_4 \cdot H_2O$	3×10^{-6}	
22	Iodic	HIO_3	1.9×10^{-1}		Isoamylamine	$C_5H_{13}N$	5×10^{-4}	
23	Isobutyric	$C_4H_8O_2$	1.5×10^{-5}		Isobutylamine	$C_4H_{11}N$	3.1×10^{-4}	
24	Isovaleric	$C_5H_{10}O_2$	1.7×10^{-5}		Isopropylamine	C_3H_9N	5.3×10^{-4}	
25	Lactic	$C_3H_6O_3$	1.38×10^{-4}		Lead hydroxide	$Pb(OH)_2$		3×10^{8}
26	Maleic	$C_4H_4O_4$	1.5×10^{-2}	2.6×10^{-7}	Methylamine	CH_5N	5×10^{-4}	
27	Malic	$C_4H_6O_5$	4×10^{-4}	9×10^{-6}	Methylethylamine	C_3H_9N	2.7×10^{-4}	
28	Malonic	$C_3H_4O_4$	1.61×10^{-3}	2.1×10^{-6}	α-Naphthylamine	$C_{10}H_9N$	9.9×10^{-11}	
29	Mandelic	$C_8H_8O_3$	4.29×10^{-4}		β-Naphthylamine	$C_{10}H_9N$	2×10^{-10}	
30	Nicotinic	$C_6H_5O_2N$	1.4×10^{-5}		o-Phenylenediamine	$C_6H_8N_2$	3.3×10^{-10}	
31	Nitrous[1]	HNO_2	4×10^{-4}		Phenylhydrazine[3]	$C_6H_8N_2$	1.6×10^{-9}	
32	Oxalic	$H_2C_2O_4$	6.5×10^{-2}	6.1×10^{-5}	Piperidine	$C_5H_{11}N$	1.6×10^{-3}	
33	Periodic	HIO_4	2.3×10^{-2}		Propylamine (norm.)	C_3H_9N	4.7×10^{-4}	
34	Phenol	C_6H_6O	1.3×10^{-10}		Pyridine	C_5H_5N	2.3×10^{-9}	
35	Phosphoric[1]	H_3PO_4	1.1×10^{-2}	7.5×10^{-8}	Quinine[4]	$C_{20}H_{24}O_2N_2$	2.2×10^{-7}	3.3×10^{-10}
				4.8×10^{-13} (3H)	Quinoline	C_9H_7N	1×10^{-9}	
36	Phosphorous	H_3PO_3	7×10^{-3}	2×10^{-5}	Semicarbazide[3]	CH_5ON_3	2.7×10^{-11}	
37	Phthalic	$C_8H_6O_4$	1.26×10^{-3}	3.1×10^{-6}	Silver hydroxide	AgOH	1.1×10^{-4}	
38	Picolinic	$C_6H_5O_2N$	3×10^{-2}		Strychnine[4]	$C_{21}H_{22}O_2N_2$	1×10^{-7}	6×10^{-11}
39	Picric[1]	$C_6H_3O_7N_3$	1.6×10^{-1}		Tetramethylenediamine	$C_4H_{12}N_2$	5.1×10^{-4}	
40	Propionic	$C_3H_6O_2$	1.4×10^{-5}		Thiourea	CH_4N_2S	1.1×10^{-13}	
41	Salicylic	$C_7H_6O_3$	1.06×10^{-3}	1×10^{-13}	m-Toluidine	C_7H_9N	5.5×10^{-10}	
42	Selenious	H_2SeO_3	3×10^{-3}	5×10^{-8}	o-Toluidine	C_7H_9N	3.3×10^{-10}	
43	Succinic	$C_4H_6O_4$	6.6×10^{-5}	2.8×10^{-6}	p-Toluidine	C_7H_9N	2×10^{-9}	
44	Sulfamic	$C_6H_7O_3NS$	5.2×10^{-4}		Triethylamine	$C_6H_{15}N$	6.4×10^{-4}	
45	Sulfuric[1]	H_2SO_4		2×10^{-2}	Trilsobutylamine	$C_{12}H_{27}N$	2.6×10^{-4}	
46	Sulfurous	H_2SO_3	1.7×10^{-2}	5×10^{-6}	Trimethylamine	C_3H_9N	7.4×10^{-5}	
47	Tartaric	$C_4H_6O_6$	1.1×10^{-3}	6.9×10^{-5}	Trimethylenediamine	$C_3H_{10}N_2$	3.5×10^{-4}	
48	Trichloracetic[1]	$C_2HO_2Cl_3$	2×10^{-1}		Tripropylamine	$C_9H_{21}N$	5.5×10^{-4}	
49	Uric	$C_5H_4O_3N_4$	1.5×10^{-6}		Urea	CH_4ON_2	1.5×10^{-14}	
50	Valeric	$C_5H_{10}O_2$	1.6×10^{-5}		Zinc hydroxide	$Zn(OH)_2$		1.5×10^{-9}

/1/ At 18°C. /2/ At 17°C. /3/ At 40°C. /4/ At 15°C.

8. AMINO ACIDS: IONIZATION CONSTANTS AND pH VALUES

Determinations were made at the isoelectric points of the amino acids in water at 25°C.

	Amino Acid	Classical				Zwitterionic				Acidic				pH
		pK_{a1}	pk_{a2}	pk_{b1}	pk_{b2}	pK_{A1}	pK_{A2}	pK_{B1}	pP_{B2}	pK_1	pK_2	pK_3	pK_4	
1	DL-Alanine	9.866		11.649		2.348		4.131		2.348	9.866			6.107
2	L-Arginine	12.48		4.96	11.99	2.01		1.52	4.96	2.01	9.04	12.48		10.76
3	L-Aspartic acid	3.86	9.82	11.93		2.10	3.86	4.18		2.10	3.86	9.82		2.98
4	L-Cystine	8.00	10.25	11.95	12.96	1.04	2.05	3.75	6.00	1.04	2.05	8.00	10.25	5.02
5	L-Dioxdytyrosine	6.48	7.82	11.88		2.12	6.48	6.18		2.12	6.48	7.82		4.29
6	L-Glutamic acid	4.07	9.47	11.90		2.10	4.07	4.53		2.10	4.07	9.47		3.08
7	Glycine	9.778		11.647		2.350		4.219		2.350	9.778			6.064
8	L-Histidine	9.18		7.90	12.23	1.77		4.82	7.90	1.77	6.10	9.18		7.66
9	Hydroxy-L-proline	9.73		12.08		1.92		4.27		1.92	9.73			5.82
10	DL-Isoleucine	9.758		11.679		2.318		4.239		2.318	9.758			6.038
11	DL-Leucine	9.744		11.669		2.328		4.253		2.328	9.744			6.036
12	L-Lysine	10.53		5.05	11.82	2.18		3.47	5.05	2.18	8.95	10.53		9.47
13	DL-Methionine	9.21		11.72		2.28		4.79		2.28	9.21			5.74
14	DL-Phenylalanine	9.24		11.42		2.58		4.76		2.58	9.24			5.91
15	L-Proline	10.60		12.0		2.00		3.40		2.00	10.60			6.3
16	DL-Serine	9.15		11.79		2.21		4.85		2.21	9.15			5.68
17	L-Tryptophan	9.39		11.62		2.38		4.61		2.38	9.39			5.88
18	L-Tyrosine	9.11	10.07	11.80		2.20	9.11	3.93		2.20	9.11	10.07		5.63
19	DL-Valine	9.719		11.711		2.286		4.278		2.286	9.719			6.002

Part I: NATURAL MONOSACCHARIDES: ALDOSES[1,2]

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
1	D-Glyceraldehyde ($C_3H_6O_3$)		+13.5±0.5 (sirup)
2	D-Glyceraldehyde dimethyl acetal	BP_{14}, 124-127	+21.8 (c 6.5, H_2O)
3	2, 3-O-Isopropylidene-D-glyceraldehyde	$BP_{0.8}$, 18-20	+64.9 (c 5.7, C_6H_6)
4	D-Glyceraldehyde dimethone	199-201	+197.5 (c 0.7, C_2H_2O)
5	D-L-Glyceraldehyde dimethone	197.5 (clouds at 190, melts at 210-211)	
6	D-Glyceraldehyde 2, 4-dinitrophenylhydrazone	155-156	
7	D-L-Glyceraldehyde 2, 4-dinitrophenylhydrazone	166-167	
8	D-L-Glyceraldehyde 2, 4-dinitrophenylosazone anhydride	310-311	
9	D-Glyceraldehyde semicarbazone	133	
10	D-Glyceraldehyde, 3, 3-bis-C-(hydroxymethyl)- (apiose) ($C_5H_{10}O_5$)		+5.6 (c 10) [15°] (sirup)
11	Apionic acid		-20 ⟶ -34.6 (H_2O)
12	Apionic acid phenylhydrazide	127	+30 (H_2O)
13	Apiose benzyl phenylhydrazone	137-138	-78.5 (c 5, C_5H_5N)[579]
14	D-α-Arabinose ($C_5H_{10}O_5$)	155	-175 ⟶ -103
15	D-Arabinose benzylphenyl-hydrazone	177-178	+14.4 (CH_3OH) [16°]
16	D-Arabinose p-bromophenyl-hydrazone	163	
17	D-Arabinose diphenylhydrazone	206	
18	Tri-O-acetyl-β-D-arabopyr-anosyl	139	-283.4 ($CHCl_3$)
19	Methyl α-D-arabofuranoside	65-67	+123 (c 1.2, H_2O)
20	Methyl β-D-arabopyranoside	168	-241.1 (H_2O)
21	Methyl 2-O-methyl-β-D-arabinoside	62-63	-205 (c 1.8, CH_3OH)
22	2-O-Methyl-D-arabinose	Sirup	-102 (c 1.5, H_2O)
23	2-O-Methyl-D-arabinose p-toluenesulfonylhydrazone	143 d.	-17.0 (c 1, H_2O)
24	2, 4-Di-O-methyl-D-arabinose	Sirup	-30.8 (c 2.4, H_2O)
25	2, 4-Di-O-methyl-D-arabinose anilide	142-143	
26	Methyl 2, 3, 5-tri-O-methyl-D-arabofuranoside	Sirup	+80.4 (c 1.1, H_2O) [20°]
27	2, 3, 5-Tri-O-methyl-D-arabo-furanose	Sirup	+40 (c 2.9, CH_3OH)[14,5]
28	D-L-Arabinose ($C_5H_{10}O_5$) (See also β-D-arabinose for hydrazones and bromide)	158 amorph.	+55.4 ⟶ +105
29	β-L-Arabinose ($C_5H_{10}O_5$)	160	+190.6 ⟶ 104.5
30	L-Lyxose, 3-C-formyl-5-deoxy- (streptose) ($C_6H_{10}O_5$)	(concluded)	
64	2, 3-Di-O-acetyl-L-streptosonic acid monolactone	186-188	+26 (c 0.5, CH_3OH)
65	L-Streptosonic acid diamide	135-136	+14 (c 0.5, H_2O)
66	D-Ribose ($C_5H_{10}O_5$)	87	-23.1 ⟶ -23.7
67	D-Ribose p-bromophenyl-hydrazone	164-165	+10.3 (c 1, C_2H_5OH), 19.3 (c 1, C_5H_5N)
68	D-Ribose benzylphenyl-hydrazone	127-128	-26.5 (c 3, C_2H_5OH)
69	1, 2, 3, 5-Tetra-O-acetyl-D-ribofuranoside	82	-12.6 (c 12, $CHCl_3$)
70	Tetra-O-acetyl-D-ribo-pyranoside	110	-52 (c 3, $CHCl_3$)
71	Methyl D-ribofuranoside	Sirup	+13.1 (c 1.9, CH_3OH)
72	Methyl D-ribopyranoside	Sirup	-39.5 ($CHCl_3$)
73	Methyl β-D-ribopyranoside	83-84	-113.6 (c 1, H_2O)
74	Methyl 2, 3, 4-Tri-O-methyl-D-ribopyranoside	Sirup	-35 (c 2.5, H_2O)
75	2, 3, 4-Tri-O-methyl-D-ribopyranose	85-86	-51 ⟶ -40 (c 1, H_2O)
76	Methyl 2, 3, 5-tri-O-methyl-D-ribofuranoside	Sirup	+59.1 (c 4.7, CH_3OH)
77	2, 3, 5-Tri-O-methyl-D-ribofuranose	Sirup	+41.1 (c 1, CH_3OH)
78	2, 3, 5-Tri-O-methyl-D-ribose aldide	56.5	
79	β-D-Ribose, 2-deoxy- (D-erythro-2-deoxyaldopentose) ($C_5H_{10}O_4$)	96-98	-91 ⟶ -58
80	2-Deoxy-D-ribose benzyl-phenylhydrazone	128	-17.5 (c 2, C_5H_5N)
81	2-Deoxy-D-ribose p-nitro-phenylhydrazone	160	-11.1 [14°] (c 0.1, C_2H_5OH)
82	2-Deoxy-D-ribose anilide	175-176	+20.5 (C_2H_5OH)
83	1, 3, 4-Tri-O-acetyl-2-deoxy-D-ribopyranoside	98	-171.8 (c 0.5, $CHCl_3$)
84	Methyl 2-deoxy-D-ribo-furanoside (α, β mixture)	Sirup	+38.4 (c 0.6, CH_3COOH)
85	Methyl 3, 5-di-O-p-tolylsulfonyl-D-ribofuranoside (α, β mixture)	Sirup	-121 (c 0.4, $CHCl_3$)
86	Methyl 3-4-di-O-p-tolylsulfonyl-β-D-ribopyranoside	104-107	-115.5 (c 6.7, $CHCl_3$)
87	D-Ribose, 2-C-hydroxymethyl- (hamamelose) ($C_5H_{10}O_5$)		-7.1 [578]
88	Hamamelose p-nitrophenyl hydrazone	165-166	+144[578] (c 4, C_5H_5N)
89	Methyl hamameloside	Sirup	-75 (c 5, CH_3OH)
90	Methyl tri-O-acetyl hamameloside	72.5	-34.8 [Hg] (c 4.1, C_2H_5OH)
91	Ammonium hamamelonate	152	-3.9 [578] (c 10, H_2O)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	D-α-Xylose ($C_5H_{10}O_5$) (concluded)		
122	2, 4-Di-O-methyl-D-xylose anilide	155-157	-40 [70°] (c 0.7, $CH_3COCl_2H_5$)
123	2, 4-Di-O-methyl-D-xylose anilide	170	-82 (dioxane)
124	Methyl 2, 4-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylopyranoside	88	-58.9 (c 1, $CHCl_3$)
125	Methyl 2, 4-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylopyranoside	75-76	+28.8 (c 1, $CHCl_3$)
126	Methyl 2, 5-di-O-methyl-α-D-xylofuranoside	Sirup	+54.3
127	Methyl 2, 5-di-O-methyl-β-D-xylofuranoside	Sirup	-56 (c 2.3, $CHCl_3$)
128	2, 5-Di-O-methyl-D-xylo-furanose	Sirup	+46 (c 1.2, H_2O)
129	Methyl 2, 5-di-O-methyl-3-O-p-tolylsulfonyl-α-D-xylofuranoside	Sirup	+34.7 [17°] (c 2, $CHCl_3$)
130	Methyl 2, 5-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylofuranoside	Sirup	-49.9 [18°] (c 1.8, $CHCl_3$)
131	Methyl 3, 4-di-O-methyl-β-D-xylopyranoside	89-90	-82 (c 2.1, $CHCl_3$)
132	3, 4-Di-O-methyl-D-xylose	Sirup	+24.9 ⟶ +20.5 (c 2.2, H_2O)
133	Methyl 3, 4-di-O-methyl-2-O-p-tolylsulfonyl-β-D-xylopyranoside	105	-34.8 (c 1.6, $CHCl_3$)
134	3, 5-Di-O-methyl-D-xylose	Sirup	+25 (c 1.1, H_2O)
135	Methyl 2, 3, 4-tri-O-methyl-β-D-xylopyranoside	49-50	-73 (c 0.8, $CHCl_3$)
136	Methyl 2, 3, 4-tri-O-methyl-α-D-xylopyranoside (with some β?)	Sirup	+86 (c 2, CH_3OH)
137	2, 3, 4-Tri-O-methyl-D-xylopyranose	91-92	+95.5 (c 1.2, HCl-alc) +64 ⟶ +18 (c 1, H_2O)
138	Methyl 2, 3, 5-tri-O-methyl-α-D-xylofuranoside	Sirup	+32 (c 0.8, CH_3OH)
139	2, 3, 5-Tri-O-methyl-D-xylofuranose	Sirup	+24.7 ⟶ +29.5 (H_2O)
140	1, 2, 3, 5-Tetra-O-acetyl-D-xylofuranoside	Sirup	+56 (C_2H_5OH)
141	D-Allose, 6-deoxy- ($C_6H_{12}O_5$)	140-143	+1.6 [18°] (c 0.6)
142	6-Deoxy-D-allose p-bromo-phenylhydrazone	138-140	
143	1, 2, 3, 4-Tetra-O-acetyl-6-deoxy-D-allopyranoside	109-110	+10.4 (c 2, $CHCl_3$)
144	D-Allose, 2, 6-dideoxy- (digitoxose) (2, 6-dideoxy-D-ribo-hexose) ($C_6H_{12}O_4$)	110	+46.4
145	Digitoxose phenylhydrazone	204-209	+215 (C_5H_5N, C_2H_5OH)
146	Digitoxose oxime	102	
147	D-Allose, 2, 6-dideoxy-3-O-methyl- (cymarose) ($C_7H_{14}O_4$)	93	+52
148	Methyl α-D-cymaroside	34-36	+210±2 [14°] (c 1.3, CH_3OH)

	(See also β-D-arabinose for hydrazones and bromides)		
30	Tetra-O-acetyl-α-L-arabopyranoside	97	+42.5 (c 3, $CHCl_3$)
31	Tetra-O-acetyl-β-L-arabopyranoside	86	+147.2 (c 5, $CHCl_3$)
32	2, 3, 4, 5-Tetra-O-acetyl-L-arabinose	113-115	-65.6 (c 4, $CHCl_3$)
33	Methyl α-L-arabofuranoside		-125 (c 1.2, H_2O)
34	Methyl α-L-arabopyranoside	131	+17.3 (c 3, H_2O)
35	Methyl β-L-arabopyranoside	166-169	+245 (c 7, H_2O)
36	Methyl 2-O-methyl-β-L-arabopyranoside	63-65	+208 (c 2.5, CH_3OH)
37	2-O-Methyl-L-arabinose	Sirup	+100 (c 5, H_2O)
38	2-O-Methyl-L-arabinose phenylhydrazone	114-116	
39	3-O-Methyl-L-arabinose	Sirup	+110 (c 3.6, H_2O)
40	3-O-Methyl-L-arabinose anilide	117	
41	2, 3-Di-O-methyl-L-arabinose	Sirup	+107 (c 1, H_2O)
42	2, 3-Di-O-methyl-L-arabinose anilide	139	
43	2, 4-Di-O-methyl-L-arabinose	Sirup	+30.8[5]
44	Methyl 2, 5-di-O-methyl-L-arabofuranoside	Sirup	-60 (c 1, H_2O)
45	2, 5-Di-O-methyl-L-arabinose	Sirup	-2 (c 1, H_2O)
46	Methyl 3, 4-di-O-methyl-β-L-arabopyranoside	Sirup	+210.6 (c 3.8, $CHCl_3$)
47	3, 4-Di-O-methyl-L-arabinose	Sirup	+116 (c 4.2, H_2O)
48	Methyl 2, 3, 4-tri-O-methyl-α-L-arabopyranoside[6]	46-48	+46.2 (c 1, H_2O)
49	Methyl 2, 3, 4-tri-O-methyl-β-L-arabopyranoside[6]	44-46	+250 (c 1, H_2O)
50	2, 3, 4-Tri-O-methyl-L-arabinose	Sirup	+127 (c 8, H_2O)
51	2, 3, 5-Tri-O-methyl-L-arabinose	Sirup	0 (c 1, H_2O)
52	Tri-O-acetyl-β-L-arabopyranosyl bromide	139	+287.1 (c 2, $CHCl_3$)
53	D-L-Arabinose ($C_5H_{10}O_5$) (See D- and L-arabinose for derivatives)	163.5-164.5	None
54	α-L-Lyxose ($C_5H_{10}O_5$)	105	+5.8 ⟶ +13.5
55	L-Lyxose p-bromophenylhydrazone	157	
56	L-Lyxose p-nitrophenylhydrazone	172	
57	Tetra-O-acetyl-α-L-lyxose[7]	93-94	+25 ($CHCl_3$)
58	Methyl α-L-lyxopyranoside[7]	108-109	+59.4 (c 5, $(H_2C$
59	Methyl β-L-lyxopyranoside[7]	118	-128.1 (c 2, H_2O)
60	Methyl 2, 3, 4-tri-O-methyl-α-L-lyxoside[7]	Sirup	+10 [346] (c 2.6, H_2O)
61	2, 3, 4-Tri-O-methyl-α-L-lyxose[7]	79	-10 ⟶ -22 (c 2, H_2O)
62	2, 3, 5-Tri-O-methyl-α-L-lyxose[7]	Sirup	+39 (c 1, H_2O)
63	L-Lyxose, 3-C-Formyl-5-deoxy-(streptose) ($C_6H_{12}O_4$) L-Streptosonic acid monolactone	146-148	-37 (c 0.7, H_2O)

92	Hamamelonic acid phenylhydrazide	202-203	+35.2 [578] (c 4, 50% CH_3COOH, C_5H_5N)
93	α-D-Xylose ($C_5H_{10}O_5$)	145	+93.6 ⟶ +18.8
94	D-Xylose p-nitro phenylhydrazone	156	
95	D-Xylose benzylphenylhydrazone	99	-20.3 (CH_3OH)
96	D-Xylose p-bromophenylhydrazone	128	-20.7 (H_2O)
97	1, 2, 3, 4-Tetra-O-acetyl-α-D-xylopyranoside	59	+89.3 (c 5, $CHCl_3$)
98	1, 2, 3, 4-Tetra-O-acetyl-β-D-xylopyranoside	128	-24.7 (c 5, $CHCl_3$)
99	2, 3, 4, 5-Tetra-O-acetyl-aldehydo-D-xylose	87-89	-15.9 [$2_6$0] (c 4, $CHCl_3$)
100	Methyl D-xylofuranoside (furanose form ?)	Sirup	+62.8 (C_2H_5OH)
101	Methyl α-D-xylopyranoside	90-92	+153.9 (c 11, H_2O)
102	Methyl β-D-xylopyranoside	157	-65.5 (c 13, H_2O)
103	Methyl 2-O-methyl-β-D-pyranoside	111-112	-67.7 (c 1.4, $CHCl_3$)
104	2-O-Methyl-β-D-xylose	132-133	-23.9 ⟶ +35.9 (c 4, H_2O)
105	3-O-Methyl-α-D-xylose	103-104	+55 ⟶ +17 (c 2, H_2O)
106	3-O-Methyl-α-D-xylose	95	+45 ⟶ +19 (c 1.6, H_2O)
107	3-O-Methyl-α-D-xylose	98-101	
108	3-O-Methyl-D-xylose anilide	137	
109	5-O-Methyl-D-xylose	Sirup	+32.8 ⟶ +36 (c 2, H_2O)
110	1, 2-O-Isopropylidene-3-O-polyallulfonyl-5-O-methyl-D-xylose	81-82	-31.8 (c 2.4, $CHCl_3$)
111	Methyl 3-O-p-tolyiaulfonyl-5-O-methyl-β-D-xylofuranoside	Sirup	-51.7 [18^0] (c 1.8, $CHCl_3$)
112	Methyl 3-O-p-tolyiaulfonyl-5-O-methyl-α-D-xylofuranoside	Sirup	+44.5 [7^0] (c 2.2, $CHCl_3$)
113	Methyl 2, 3-di-O-methyl-D-xyloside (a form?)	Sirup	+61.8 (c 1.2, CH_3OH)
114	Methyl 2, 3-di-O-methyl-D-xyloside (β form ?)	Sirup	-5.8 (c 2.2, $CHCl_3$)
115	2, 3-Di-O-methyl-D-xylose (α form?)	79-80	+70 ⟶ +23 (c 1, H_2O) [18^0]
116	Methyl 2, 3-di-O-methyl-4-O-p-tolyiaulfonyl-β-D-xylopyranoside	56-59	-8.8 (c 2.5, $CHCl_3$)
117	Methyl 2, 4-di-O-methyl-β-D-xylopyranoside	77.5-78.5	-70 (c 1, $CHCl_3$)
118	Methyl 2, 4-di-O-methyl-β-D-xylopyranoside	60-61	-82.4 (c 1.4, $CHCl_3$)
119	2, 4-Di-O-methyl-D-xylose (β form ?)	108	-30 ⟶ +22 (H_2O)
120	2, 4-Di-O-methyl-D-xylose	111	-13 ⟶ +23 (c 2, H_2O)
121	2, 4-Di-O-methyl-D-xylose	116-118	-26 (c 1, $CHCl_3$)

149	D-Cymaronic acid phenylhydrazide	155-156	+1.4a3, [16^0] (c 0.7, CH_3OH)
150	Antiarose ($C_6H_{12}O_5$)		Levo
151	Antiaronic acid lactone		-30
152	Antiaronic acid phenylhydrazide	143-145	
153	α-D-Galactose ($C_6H_{12}O_6$) See β-D-galactose	167	+150.7 ⟶ +80.2
154	β-D-Galactose ($C_6H_{12}O_6$)		+52.8 ⟶ +80.2
155	D-Galactose α-tolylhydrazone	176	
156	D-Galactose p-bromophenylhydrazone	166-167	
157	D-Galactose p-nitrophenylhydrazone	196-197	
158	D-Galactose benzylphenylhydrazone	157-158	
159	2, 3, 4, 5, 6-Penta-O-acetyl-aldehydo-D-galactose	121	-25 [26^0] (c 4, $CHCl_3$)
160	1, 2, 3, 5, 6-Penta-O-acetyl-α-D-galactofuranoside	87	+61.2 (c 4, $CHCl_3$)
161	1, 2, 3, 5, 4-Penta-O-acetyl-β-D-galactofuranoside	98	-41.6 ($CHCl_3$)
162	1, 2, 3, 4, 6-Penta-O-acetyl-α-D-galactopyranoside	96	+106.7 (c 3, $CHCl_3$)
163	1, 2, 3, 4, 6-Penta-O-acetyl-β-D-galactopyranoside	142	+25 ($CHCl_3$)
164	Methyl α-D-galactopyranoside monohydrate	110	+179.3 (c 9, H_2O)
165	Methyl β-D-galactopyranoside	178	0 (c 10, H_2O)
166	Methyl 2-O-methyl-α-D-galactopyranoside	Sirup	+180 (c 3.5, CH_3OH)
167	Methyl 2-O-methyl-β-D-galactopyranoside	131-132	+1.7 (c 11, H_2O)
168	2-O-Methyl-β-D-galactopyranose	147-149	+53 ⟶ +86.2 (c 5, H_2O)
169	Methyl 3-O-methyl-β-D-galactopyranoside	Sirup	+31.9 (c 5, H_2O)
170	α-D-Galactopyranose, 3-O-methyl- ($C_7H_{14}O_6$)	144-147	+150.6 ⟶ +108.6
171	4-O-Methyl-β-D-galactopyranose	207	+62 ⟶ +92 (c 1.5, H_2O)
172	Methyl 6-O-methyl-β-D-galactofuranoside (?)	Sirup	-78.7 (c 3.3, H_2O)
173	6-O-Methyl-α-D-galactopyranose	113-114	+137 ⟶ +77 (c 3, H_2O)
174	Methyl 2, 3-di-O-methyl-α-D-galactopyranoside	Sirup	+210 (H_2O)
175	Methyl 2, 3-di-O-methyl-β-D-galactopyranoside	Sirup	+23 (H_2O)
176	2, 3-Di-O-methyl-β-D-galactopyranose	Sirup	+57 ⟶ +105 (H_2O)
177	Methyl 2, 4-di-O-methyl-α-D-galactopyranoside	105	+142 (c 1.1, H_2O)
178	Methyl 2, 4-di-O-methyl-β-D-galactopyranoside	165-166	0 (c 1.8, H_2O)
179	2, 4-Di-O-methyl-D-galactopyranose	103	+122 ⟶ +85.6 (c 1.7, H_2O)
180	Methyl 2, 6-di-O-methyl-β-D-galactopyranoside	72	-22 (c 1, $CHCl_3$)
181	2, 6-Di-O-methyl-β-D-galactopyranose	106-108	+45 ⟶ +88 (c 5.4, H_2O)

Part I: NATURAL MONOSACCHARIDES: ALDOSES[1, 2] (Continued)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	α-D-Galactopyranose, 3-O-methyl ($C_7H_{14}O_6$) (concluded)		
182	2, 6-Di-O-methyl-β-D-galactopyranose	128-130	+46.8 ⟶ +87.5 (c 6.3, H_2O)
183	Methyl 3, 4-di-O-methyl-β-D-galactopyranoside	102-103	-9.1 (c 5.2, $CHCl_3$)
184	3, 4-Di-O-methyl-β-D-galactopyranose	164-166	+95 ⟶ +117 (c 4.5, H_2O)
185	Methyl 4, 6-di-O-methyl-β-D-galactopyranoside	140	-41.5 (c 4, $CHCl_3$)
186	4, 6-Di-O-methyl-α-D-galactopyranose	131-133	+133 ⟶ +76.9 (c 2.4, H_2O)
187	Methyl 2, 3, 4-tri-O-methyl-α-D-galactopyranoside	30	+198.4 (c 1, H_2O)
188	2, 3, 4-Tri-O-methyl-α-D-galactopyranose	85	+154.1 ⟶ +122 (c 2, H_2O)
189	Methyl 2, 3, 5-tri-O-methyl-D-galactofuranoside		-55 (c 1.2, H_2O)
190	2, 3, 5-Tri-O-methyl-D-galactose	Sirup	-5 (c 0.8, H_2O)
191	2, 3, 5-Tri-O-methyl-D-galactonic acid phenylhydrazide	144	+18 [18^0] (c 1.2, C_2H_5OH)
192	2, 3, 6-Tri-O-methyl-D-galactose	Sirup	+87 (H_2O)
193	2, 3, 6-Tri-O-methyl-D-galactonic acid phenylhydrazide	175	-62.4 (c 1, --)
194	Methyl 2, 4, 6-tri-O-methyl-α-D-galactopyranoside	73-74	+163.9 (c 1, H_2O)
195	Methyl 2, 4, 6-tri-O-methyl-β-D-galactopyranoside	111-112	-40.9 (c 5, $CHCl_3$)
196	2, 4, 6-Tri-O-methyl-α-D-galactopyranose	102-105	+124 ⟶ +90.4 (c 3.4, H_2O)
197	3, 4, 6-Tri-O-methyl-D-galactose	Sirup	-4.3 (c 4.2, CH_3OH)
198	3, 4, 6-Tri-O-methyl-D-galactonic acid lactone	Sirup	+46.8 (c 2.5, H_2O)
199	Methyl 2, 3, 4, 6-tetra-O-methyl-α-D-galacto-pyranoside	Sirup	+190 (H_2O)
200	Methyl 2, 3, 4, 6-tetra-O-methyl-β-D-galacto-pyranoside	48-49	+18.7 (H_2O)
201	2, 3, 4, 6-Tetra-O-methyl-α-D-galactopyranose	71	+142 ⟶ +118
202	Methyl 2, 3, 5, 6-tetra-O-methyl-D-galactoside	Sirup	-45.2 (c 1.4, H_2O)
203	Methyl 2, 3, 5, 6-tetra-O-methyl-D-galactofuranoside	48-48.5	+19.6 (c 1, H_2O)
204	2, 3, 5, 6-Tetra-O-methyl-D-galactopyranose	Sirup	-21.2 (c 2, H_2O)
205	2, 3, 5, 6-Tetra-O-methyl-D-galactonic acid lactone	Sirup	-27.1 ⟶ +25 (c 1.5, H_2O)
	α-D-Galactose, 2-amino-2-deoxy-(chondrosamine) (galactosamine) ($C_6H_{13}NO_5$)		
206	α-D-Galactosamine hydrochloride	185	+121 ⟶ +80 (c 2, HCl-H_2O)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	L-Galactose ($C_6H_{12}O_6$) (See derivatives of D-galactose)		(See D-galactose)
	L-Galactose[8], 3, 6-anhydro-(L-$C_6H_{10}O_5$)		
234	Methyl 2, 4-di-O-methyl-3, 6-anhydro-L-galacto-pyranoside	82	+75 [14^0] (c 5.6, H_2O)
235	2, 4-Di-O-methyl-3, 6-anhydro-L-galactose	Sirup	-23
236	Methyl 3, 6-anhydro-β-L-galactoside	118	-113.5 (c 1, H_2O)
237	α-L-Galactose, 6-deoxy-(L-fucose) ($C_6H_{12}O_5$)	145	-124.1 ⟶ -76.4
238	Methyl α-L-fucoside (See also D-galactose, 6-deoxy-)	154-156	-197 [15^0] (c 1.1, H_2O)
239	Methyl 3-O-methyl-α-L-fucopyranoside	130-132	-173 [14^0] (c 0.4, H_2O)
240	3-O-Methyl-L-fucose	Sirup	-94 [15^0] (c 0.5, H_2O)
241	Methyl 2, 3, -di-O-methyl-α-L-fucopyranoside	49-51	-190 [19^0] (c 1.4, H_2O)
242	2, 3-Di-O-methyl-L-fucose	Sirup	+4.6 [19^0] (c 3, H_2O)
243	Methyl 3, 4-di-O-methyl-α-L-fucopyranoside	100	-213 (c 1.3, H_2O)
244	3, 4-Di-O-methyl-L-fucose	76, 82	-118 [19^0] (c 1.1, H_2O)
245	Methyl 2, 3, 4-tri-O-methyl-α-L-fucopyranoside	97-98	-209 (H_2O)
246	Methyl 2, 3, 4-tri-O-methyl-β-L-fucopyranoside	101.5 ⟶ 102.5	-21 (H_2O)
247	2, 3, 4-Tri-O-methyl-α-L-fucose	36-37	-184 ⟶ -128 (H_2O)
248	Methyl β-L-fucoside	120-122	+15.5 (c 2, H_2O)
249	α-L-Galactose ($C_6H_{12}O_6$)	143-144, 163	None
	(See derivatives of D-galactose)		
250	α-D-Glucose ($C_6H_{12}O_6$)	146	+112.2 ⟶ +52.7
	(See β-D-glucose)		
251	α-D-Glucose monobydrate ($C_6H_{12}O_6H_2O$)	83	+102 ⟶ +47.9
252	D-Glucose p-bromophenyl-hydrazone (See also β-D-glucose)	164-166	
253	β-D-Glucose ($C_6H_{12}O_6$)	148-150	+18.7 ⟶ +52.7
254	D-Glucose p-nitrophenyl-hydrazone	189	+21.5 ($C_{12}H_{15}N_3O_7$)
255	D-Glucose benzylphenyl-hydrazone	150, 158	
256	Penta-O-acetyl-α-D-glucopyranose	114	+101.6 (c 5, $CHCl_3$)
257	Penta-O-acetyl-β-D-glucopyranose	135	+3.8 (c 7, $CHCl_3$)
258	Penta-O-acetyl-aldehydo-D-glucose	119-120	-4.2 (c 3, $CHCl_3$)
259	Methyl α-D-glucofuranoside	62-63	+118 (c 5, H_2O)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	β-D-Glucose ($C_6H_{12}O_6$) (concluded)		
289	4, 6-Di-O-methyl-α-D-glucose	156-158	+110 ⟶ +65.7 (c 4, H_2O)
290	5, 6-Di-O-methyl-α-glucose	Sirup	+4.0 [32^0] (c 2, H_2O)
291	Methyl 2, 3, 4-tri-O-methyl-β-D-glucopyranoside	93-94	-19.6 (c 5, H_2O)
292	2, 3, 4-Tri-O-methyl-D-glucose	Sirup	+50 (c 4, H_2O)
293	Methyl 2, 3, 5-tri-O-methyl-α-glucofuranoside	Sirup	-11 (c 1.8, H_2O)
294	2, 3, 5-Tri-O-methyl-α-glucose	Sirup	+17 (c 1.8, H_2O)
295	Methyl 2, 3, 6-tri-O-methyl-α-α-glucopyranoside		+149 (c 2, CH_3OH)
296	Methyl 2, 3, 6-tri-O-methyl-β-α-glucopyranoside	58-60	-48 (c 5, $CHCl_3$)
297	2, 3, 6-Tri-O-methyl-α-α-glucose	121-123	+90 ⟶ +70.5 (H_2O)
298	Methyl 2, 4, 6-tri-O-methyl-β-α-glucopyranoside	70-71	-27.4 (c 5, $CHCl_3$)
299	2, 4, 6-Tri-O-methyl-α-α-glucose	123	+89.7 ⟶ +71.5 (c 2, H_2O)
300	Methyl 3, 4, 6-tri-O-methyl-β-α-glucopyranoside	52-53	-16.4 (c 2, $CHCl_3$)
301	3, 4, 6-Tri-O-methyl-α-α-glucose	76-77	+91.9 ⟶ +77.4 (c 4, H_2O)
302	3, 4, 6-Tri-O-methyl-β-D-glucose	97-98	+41.1 ⟶ +77.5 (c 1.6, H_2O)
303	Methyl 3, 5, 6-tri-O-methyl-α-α-glucofuranoside	Sirup	+93 (c 3.1, CH_3OH)
304	Methyl 2, 3, 6-tri-O-methyl-β-α-glucofuranoside	Sirup	-87 (c 2.8, CH_3OH)
305	3, 5, 6-Tri-O-methyl-α-glucose	Sirup	-25.9 (c 1, H_2O)
306	Methyl tetra-O-methyl-α-D-glucopyranoside	Sirup	+147.2 (c 10, H_2O)
307	Methyl tetra-O-methyl-β-D-glucopyranoside	40-41	-17.3 (c 4, H_2O)
308	Tetra-O-methyl-α-D-glucopyranose	88-89	+100 ⟶ +83.3 (c 5, H_2O)
309	Tetra-O-methyl-β-D-glucopyranose	50	+73.1 ⟶ +83.1 (c 5, H_2O)
310	Methyl tetra-O-methyl-α-D-glucofuranoside	11	+107 [10^0] (c 0.7, H_2O)
311	Methyl tetra-O-methyl-β-D-glucofuranoside	Sirup	-72.7 (CH_3OH)
312	Tetra-O-methyl-α-D-glucofuranose	Sirup	-7.6 (c 0.9, H_2O)
313	β-Glucose, 6-benzoyl-(vaccinin) ($C_{13}H_{16}O_7$)	Amorph.	+48 (C_2H_5OH)
314	1, 2, 3, 4-Tetra-O-acetyl-6-O-benzoyl-β-α-glucose	132	+32.9 ($CHCl_3$)
315	β-Glucose[9], 2-deoxy-($C_6H_{12}O_5$)	148	+46.6 [18^0]
316	2-Deoxy-β-glucose benzyl-phenylhydrazone	158-159	
317	α-D-Glucose, 2-deoxy-2-amino-(chitosamine) (glucosamine) ($C_6H_{13}NO_5$)	88	+100 ⟶ +47.5

207	β-n-Galactosamine hydrochloride	187	+44.5 ⟶ +80 (c 2, HCl-H_2O)
208	N-Acetyl-n-galactosamine	120-122	+115 ⟶ +80 (H_2O)
209	N-(2, 4-Dinitrophenyl)-n-galactosamine	184-186	+84 [546] (c 1, 80% C_2H_5OH)
210	1, 3, 4, 6-Tetra-O-acetyl-N-acetyl-α-n-galactosamine	178	+102 (c 1.6, $CHCl_3$)
211	1, 3, 4, 6-Tetra-O-acetyl-N-acetyl-β-n-galactosamine	235	+10 (c 1, $CHCl_3$)
212	Methyl N-acetyl-α-n-galactosaminide	217-218	+170 ($CHCl_3$)
213	Methyl 3, 4, 6-Tri-O-methyl-α-n-galactosamine hydrochloride	227	+150.3 (c 3.6, CH_3OH)
214	3, 4, 6-Tri-O-methyl-n-galactosamine hydrochloride	178	+114 (c 1, H_2O)
215	Methyl 3, 4, 6-Tri-O-methyl-N-acetyl-α-n-galactosaminide	185	+121 (c 1.4, $CHCl_3$)
216	Methyl 3, 4, 6-Tri-O-methyl-N-acetyl-β-n-galactosaminide	232	+7 (c 1, $CHCl_3$)
217	N-(2-Hydroxyl-1-napthylidene)-α-galactosamine	175-178	+287 ⟶ +258 (CH_3OH) [546]
218	α-n-Galactose, 6-deoxy- (α-fucose) (rhodeose)($C_6H_{12}O_5$)	140-145	+127 ⟶ +76.3 (c 10)
219	n-Fucose benzylphenyl-hydrazone	178-179	-14.9 (c 0.4, CH_3OH)
220	n-Fucose p-bromophenyl-hydrazone	184	
221	Methyl α-n-fucoside	155-156	+190 (c 4.2, H_2O)
222	Methyl β-n-fucoside	120	-14.0 (c 0.8, H_2O)
223	2-O-Methyl-n-fucose	155-161	+73 ⟶ +87 (c 1.3, H_2O)
224	Methyl 2, 3, 4-tri-O-methyl-β-n-fucopyranoside	93-98	+11.2 (c 1, H_2O)
225	2, 3, 4-Tri-O-methyl-n-fucose	Sirup	+106 (c 1, H_2O)
226	2, 3, 4-Tri-O-methyl-α-n-fucose hydrate	65	+183 ⟶ +128.8 (H_2O)
227	α-Galacto, 6-deoxy-3-O-methyl- (digitalose) ($C_7H_{14}O_5$)	106, 119	+106
228	Diginoic acid lactone	137-138	-83 (c 3.2, H_2O)
229	Methyl 3-O-methyl-α-n-fucopyranoside	Sirup	+124.4 (c 0.9, CH_3COCH_3)
230	Methyl 3-O-methyl-β-n-fucopyranoside	97-99	
231	n-Galactose, 2, 6-dideoxy-3-O-methyl- (diginose) ($C_7H_{14}O_4$)	90-92	+5$\frac{6}{4}$
232	Diginoic acid lactone	Sirup	-30 [14^0] (c 2, CH_3COCH_3
233	S-Benzylthiuronium salt of diginoic acid	137	-9.2 (CH_3OH)
260	Methyl β-n-glucofuranoside	Sirup	-77 (H_2O)
261	Methyl α-n-glucopyranoside	166	+158.9 (c 10, H_2O)
262	Methyl β-n-glucopyranoside	105	-34.2 (c 10, H_2O)
263	Methyl 2-O-methyl-α-n-glucopyranoside	147-148	+155 (c 0.7, H_2O)
264	Methyl 2-O-methyl-β-n-glucopyranoside	97-98	-37.5 (c 5, H_2O)
265	2-O-Methyl-β-n-glucose	157-158	+2 ⟶ +65.3 (c 2, H_2O)
266	Methyl 3-O-methyl-β-n-glucopyranoside	Sirup	-26 (c 5.5, H_2O)
267	3-O-Methyl-α-n-glucose	160-161	+104.3 ⟶ +55.3 (c 1, H_2O)
268	3-O-Methyl-β-n-glucose	130-132	+31.9 ⟶ +55.1 (c 1, H_2O)
269	4-O-Methyl-n-glucose	Sirup	+53 (c 2, H_2O)
270	5-O-Methyl-n-glucose	Sirup	-10.6 (c 2, C_2H_5OH)
271	Methyl 6-O-methyl-α-n-glucopyranoside	Sirup	+127.9 (H_2O)
272	Methyl 6-O-methyl-β-n-glucopyranoside	133-135	-27.0 (c 5, H_2O)
273	6-O-Methyl-α-n-glucose	143-145	+110 ⟶ +55 (c 3, H_2O)
274	Methyl 2, 3-di-O-methyl-α-n-glucopyranoside	80-82	+142.6 (c 5, H_2O)
275	Methyl 2, 3-di-O-methyl-β-n-glucopyranoside	62-64	-36.6 (c 5, H_2O)
276	2, 3-O-Methyl-α-n-glucose	85-87	+81.9 ⟶ +48.3 (c 1, CH_3COCH_3)
277	2, 3-O-Methyl-β-n-glucose	108-110	+5.9 ⟶ +50.9 (c 4, CH_3COCH_3)
278	Methyl-2, 4-di-O-methyl-α-n-glucopyranoside	79-81	+159, +186 (c 0.3-1, CH_3COCH_3)
279	Methyl 2, 4-di-O-methyl-β-n-glucopyranoside	124	-16.5[29^0] (c 0.5, CH_3COCH_3)
280	Methyl 2, 6-di-O-methyl-α-n-glucopyranoside	Sirup	+154 (c 1.5, H_2O)
281	Methyl 2, 6-di-O-methyl-β-n-glucopyranoside	50-52	+43.5 (c 11, $CHCl_3$)
282	2, 6-Di-O-methyl-n-glucose	Sirup	+58.2 (c 2.7, H_2O)
283	Methyl 3, 4-di-O-methyl-β-n-glucopyranoside	79-81	-11.9 (c 5, $CHCl_3$)
284	3, 4-Di-O-methyl-β-n-glucose	113	+64.9 ⟶ +94.8 (c 1, H_2O)
285	Methyl 3, 6-di-O-methyl-β-n-glucopyranoside	Sirup	+55.4 (c 2.5, C_2H_5OH)
286	3, 6-Di-O-methyl-α-n-glucose	113-116	+102.6 ⟶ +61.5 (c 3, H_2O)
287	Methyl 4, 6-di-O-methyl-α-n-glucopyranoside	Sirup	+157 ($CHCl_3$)
288	Methyl 4, 6-di-O-methyl-β-n-glucopyranoside	50-52	-28 (c 3, $CHCl_3$)
318	α-n-Glucosamine hydrochloride		+100 ⟶ +72.5
319	β-n-Glucose, 2-deoxy-2-amino- ($C_6H_{13}NO_4$)	110-111	+28 ⟶ +47.5
320	β-n-Glucosamine hydrochloride		+25 ⟶ +72.5
321	N-Acetyl-α-n-glucosamine	205	+64 ⟶ +40.9 (H_2O)
322	N-(2, 4-Dinitrophenyl)-n-glucosamine	202-204	+65[546] (c 1, C_2H_5OH)
323	N-(2-Hydroxy-1-naphthylidene)-α-glucosamine	202-203	+274 ⟶ +217 [546] (CH_3OH)
324	n-Glucosamine diphenyl-hydrazone	162	
325	Tetra-O-acetyl-α-α-glucosaminopyranoside	143	+25.9 ($CHCl_3$)
326	Tetra-O-acetyl-α-α-glucosaminopyranoside hydrochloride	230	+29.7 (H_2O)
327	Tetra-O-acetyl-N-acetyl-α-α-glucosaminopyranoside	139-140	+93.4 ($CHCl_3$)
328	Tetra-O-acetyl-N-acetyl-β-α-glucosaminopyranoside	187-189	+1.2 ($CHCl_3$)
329	Tetra-O-acetyl-N-acetyl-aldehydo-α-glucosamine	156-157	+36 (c 0.1, $CHCl_3$)
330	Methyl N-acetyl-β-α-glucosaminofuranoside	Sirup	-25 (c 0.8, H_2O)
331	Methyl α-α-glucosaminide hydrochloride	119	+127 (H_2O)
332	Methyl β-α-glucosaminide hydrochloride	190	-24.2 (H_2O)
333	Methyl N-acetyl-α-α-glucosaminide	188-189	+104 (H_2O)
334	Methyl N-acetyl-β-α-glucosaminide	195-196	-43 (H_2O)
335	Methyl 3-O-methyl-N-acetyl-α-α-glucosaminoside	211	+116 (H_2O)
336	3-O-Methyl-α-α-glucosamine hydrochloride	215 d.	+123 ⟶ +91.3 (H_2O)
337	Methyl 4, 6-di-O-methyl-N-acetyl-β-α-glucosaminide	187	-21.5 [16^0] (c 2.5, CH_3OH)
338	Methyl 3, 4, 6-tri-O-methyl-α-α-glucosaminide	Sirup	+169.8 (c 0.8, CH_3OH)
339	Methyl 3, 4, 6-tri-O-methyl-α-α-glucosaminide hydrochloride	237 d.	+129.6 (c 0.5, H_2O)
340	Methyl 3, 4, 6-tri-O-methyl-N-acetyl-α-α-glucosaminide	150	+104.3 (c 0.9, H_2O)
341	Methyl 3, 4, 6-tri-O-methyl-N-acetyl-β-α-glucosaminide	195	+19.6 (c 0.3, $CHCl_3$)
342	3, 4, 6-Tri-O-methyl-α-glucosamine hydrochloride	210 d.	+49.2 ⟶ +99.5 (c 1.2, H_2O)
343	3, 4, 6-Tri-O-methyl-N-acetyl-α-glucosamine	234	+75 ⟶ +44.8 (H_2O)
344	n-Glucose, 6-deoxy- (chinovose)(epirhamnose) (glucomethylose)(isorhamnose)(isorhodeose)(quinovose)($C_6H_{12}O_5$)	139-140	+75.1 ⟶ +29.7 (c 8)
345	n-Glucomethylonic acid lactone	151-152	+66.9 ⟶ +5.4 (H_2O)

Part I: NATURAL MONOSACCHARIDES: ALDOSES[1,2] (Concluded)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	D-Glucose, 6-deoxy- (chinovose)(epirhamnose) (glucomethylose)(isorhamnose)(isorhodeose)(quinovose)($C_6H_{12}O_5$) (concluded)		
346	Methyl α-D-glucomethyloside	98-99	
347	Methyl β-D-glucomethyloside	131-132	-55.1 (H_2O)
348	D-α-Glucose, 6-deoxy-3-O-methyl- (α-thevetose)($C_7H_{14}O_5$)	116	+84 ⟶ +33
349	1,2,4-Tri-O-acetyl-3-O-methyl-β-D-glucomethyloside	121	+6 (CH_3COCH_3)
350	1,2,4-Tri-O-acetyl-3-O-methyl-α-D-glucomethyloside	105	+122 (CH_3COCH_3)
351	Methyl β-D-thevetoside	116-117	-44±2 (c 1, H_2O)
352	Methyl α-D-thevetoside	86-87	+148±2 (c 1, H_2O)
353	D-α-L-Glucose ($C_6H_{12}O_6$) (See α- and β-D-glucose)	141-143	-95.5 ⟶ -51.4
354	L-Glucose, 2-deoxy-2-amino-N-methyl-($C_7H_{15}NO_5$)	130-132	-64
355	N-Methyl-α-L-glucosamine hydrochloride	160-163	-103 ⟶ -88 (c 0.6, H_2O)
356	N-Acetyl-N-methyl-L-glucosamine	165-166	-51 (c 0.5, H_2O)
357	Tetra-O-acetyl-N-acetyl-N-methyl-α-L-glucosaminide	160-161	-100 (c 0.7, $CHCl_3$)
358	Tetra-O-acetyl-N-acetyl-N-methyl-β-L-glucosaminide	153	-16.5 (c 3, $CHCl_3$)
359	L-Glucose, 6-deoxy-3-O-methyl- (thevetose)($C_7H_{14}O_5$)	126-129	-36.9±2
360	1,2,4-Tri-O-acetyl-3-O-methyl-β-L-glucomethyloside	118-119	-7.5±2 (c 1.1, CH_3COCH_3)
361	1,2,4-Tri-O-acetyl-3-O-methyl-α-L-glucomethyloside	103-104	-113 (CH_3OH)
362	L-Glucose, 2,6-dideoxy-3-O-methyl- (α-oleandrose)($C_7H_{14}O_4$)	62-63	+11.9±2.5
363	Oleandrose 2,4-dinitro-phenylhydrazone	155-160	
364	Oleandronic acid	136	+20.3 (c 0.6, CH_3OH)
365	D-Gulose, 2,6-dideoxy-3-O-methyl- (sarmentose)[10] ($C_7H_{14}O_4$)	78-79	+12 ⟶ +15.8
366	S-Benzyl-thiouronium salt of sarmentonic acid	146	+6.5±2 (c 1.2, CH_3OH)
367	D-α-Mannose ($C_6H_{12}O_6$) (See β-D-mannose)	133	+29.3 ⟶ +14.2
368	β-D-Mannose ($C_6H_{12}O_6$)	132	-16.3 ⟶ +14.5
369	D-Mannose phenylhydrazone	199-200	+26.3 ⟶ +33.8[11] (C_5H_5N)
370	D-Mannose benzylphenyl-hydrazone	170-171	+29.8 (CH_3OH)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	β-D-Mannose ($C_6H_{12}O_6$) (continued)		
373	Penta-O-acetyl-α-D-mannopyranoside	64	+55 (c 4, $CHCl_3$)
374	Penta-O-acetyl-β-D-mannopyranoside	117-118	-25.3 (c 3, $CHCl_3$)
375	Methyl α-D-mannofuranoside	118-119	118 (c 1, H_2O)
376	Methyl α-D-mannopyranoside	193-194	79.2 (c 1, H_2O)
377	Methyl β-D-mannopyranoside (isopropyl alcoholate	74-75	-53.3 (c 4, H_2O)
378	Methyl 2-O-methyl-α-D-mannofuranoside	82	+129.5 (c 2.6, H_2O)
379	2-O-Methyl-D-mannose	136-137	+7.0 ⟶ +4.5 (c 2.9, H_2O)
380	Methyl 4-O-methyl-α-D-mannopyranoside	101-102	+84.4±0.5 (c 0.8, H_2O)
381	4-O-Methyl-D-mannose	127-129	+32.4 ⟶ +22.3 (c 4, H_2O)
382	6-O-Methyl-D-mannose	Sirup	+15.3 (c 1.1, $CHCl_3$)
383	Methyl 2,3-di-O-methyl-α-D-mannoside	Sirup	+43.5 (c 2.4, $CHCl_3$)
384	2,3-Di-O-methyl-D-mannose	Sirup	+16, +22 (c 0.7-1.2, H_2O)
385	Methyl 3,4-di-O-methyl-α-D-mannopyranoside	80	+88.6 [175] ($CHCl_3$)
386	3,4-Di-O-methyl-D-mannose monohydrate	114	+22 ⟶ +4 (c 2, H_2O)
387	Methyl 4,6-di-O-methyl-α-D-mannopyranoside	Sirup	+80.5 [5780] (c 1.2, H_2O)
388	4,6-Di-O-methyl-D-mannose	Glass	+25 [5780] (c 4.3, H_2O)
389	4,6-Di-O-methyl-α-D-mannonic acid phenylhydrazide	151	+14 [5780] (c 0.9, H_2O)
390	Methyl 2,3,4-tri-O-methyl-α-D-mannopyranoside	Sirup	+58 (c 1.3, H_2O)
391	2,3,4-Tri-O-methyl-D-mannose	102-103	+18.2 ⟶ +7 [5780] (c 20, H_2O)
392	Methyl 2,3,5-tri-O-methyl-α-D-mannofuranoside	Sirup	+54 [1460] (c 1.3, H_2O)
393	2,3,5-Tri-O-methyl-γ-D-mannonolactone	118	+67 ⟶ +63.5 (c 1, H_2O)
394	Methyl-2,3,6-tri-O-methyl-α-D-mannoside	Sirup	+26 (c 0.9, H_2O)
395	2,3,6-Tri-O-methyl-D-mannose	Sirup	-6.5 (c 0.6, H_2O)
396	2,3,6-Tri-O-methyl-γ-D-mannonolactone	84-85	+65.5 [180] (c 1, H_2O)
397	Methyl 2,4,6-tri-O-methyl-α-D-mannopyranoside	Sirup	+70 (c 1, HCl in CH_3OH)
398	2,4,6-Tri-O-methyl-α-D-mannose monohydrate	89-90	+23 ⟶ +16 (c 1, H_2O)
399	2,4,6-Tri-O-methyl-β-D-mannose monohydrate	104-107	-5.7 ⟶ +19 (c 2.1, H_2O)
400	3,4,6-Tri-O-methyl-α-D-mannopyranose	101-102	+21 ⟶ +8.2 (c 1, H_2O)
401	Methyl tetra-O-methyl-α-D-mannopyranoside	39-40	+43.5 (c 5, H_2O)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
	β-D-Mannose ($C_6H_{12}O_6$) (concluded)		
404	Methyl tetra-O-methyl-α-D-mannofuranoside	24	+98.6 [190] (c 1, H_2O)
405	Tetra-O-methyl-α-D-mannofuranose (?)	Sirup	+39 ⟶ +43 (c 0.5, H_2O)
406	Methyl tetra-O-methyl-β-D-mannofuranoside	Sirup	+24.7 (c 4, CH_3OH)
407	Tetra-O-methyl-γ-D-mannonolactone	107-108	+64.8 [40] (c 1.7, H_2O)
408	D-α-L-Mannose, 6-deoxy-, monohydrate (L-rhamnose) ($C_6H_{12}O_6$) (See β-L-mannose, 6-deoxy-)	93-94	-8.6 ⟶ +8.2
409	β-L-Mannose, 6-deoxy- (L-rhamnose) ($C_6H_{12}O_5$)	123-125	+38.4 ⟶ +8.9
410	L-Rhamnose p-bromo-phenylhydrazone	169-170	
411	L-Rhamnose p-nitro-phenylhydrazone	190-191	-50 ⟶ -8.5 (C_5H_5N, C_2H_5OH)
412	L-Rhamnose benzyl-phenylhydrazone	121	-10.4 ⟶ -7.4 (CH_3OH)
413	Tetra-O-acetyl-β-L-rhamnopyranoside	98-99	+13.9 (c 15, $C_5H_5Cl_4$)
414	Methyl α-L-rhamnopyranoside	108-109	-62.5 (c 10, H_2O)
415	Methyl β-L-rhamnopyranoside	138-140	+74 (c 10, H_2O)
416	Methyl 2-O-methyl-L-rhamnopyranoside	139-140	
417	2-O-Methyl-L-rhamnose	113-114	+31 (H_2O)
418	Methyl 4-O-methyl-α-L-rhamnoside	Sirup	-50.2 (c 1.5, H_2O)
419	4-O-Methyl-L-rhamnose	125-126	+13 (c 1, CH_3OH)
420	Methyl 5-O-methyl-L-rhamnofuranoside	59-60	-89.2 (c 1, H_2O)
421	5-O-Methyl-L-rhamno-furanoside	102-103	-4.3 (c 3, H_2O)
422	Methyl 2,3-di-O-methyl-α-L-rhamnoside	Sirup	-6, +14 (c 2, H_2O)
423	2,3-Di-O-methyl-L-rhamnose	Sirup	+47.6 (c 1, H_2O)
424	2,3-Di-O-methyl-L-rhamnose anilide	136-138	
425	3,4-Di-O-methyl-L-rhamnose	91-92	-10 ⟶ +18.6 (c 1.5, H_2O)
426	3,4-Di-O-methyl-L-rhamnose	98-99	+24 ⟶ +18.5 (c 0.5, H_2O)
427	Methyl 2,3,4-tri-O-methyl-L-rhamnopyranoside (a form?)	Sirup	-15.5 (H_2O)
428	Methyl 2,3,4-tri-O-methyl-β-L-rhamnopyranoside	53-54	+106 (c 1, H_2O)
429	2,3,4-Tri-O-methyl-L-rhamnose	Sirup	+26 (c 2.5, H_2O)
430	2,3,4-Tri-O-methyl-L-rhamnose anilide	112	+127
431	L-Talose, 6-deoxy- (L-talomethylose)($C_6H_{12}O_5$)	116-118	-19.5±2 [180]

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
371	p-Mannose p-bromophenylhydrazone	208	
372	p-Mannose p-nitro phenylhydrazone	194-195, 202-203	+56 (C_5H_5N, C_2H_5OH)
402	Tetra-O-methyl-α-p-mannopyranose	50-51	+7.4 ⟶ +2.4 (H_2O)
403	Methyl tetra-O-methyl-β-p-mannopyranoside	37	-80 (c 1, H_2O)
432	L-Talomethylose p-bromophenylhydrazone	145-147	-10 ⟶ +4a3 [16°](c 0.8, C_2H_5OH)
433	L-Talonic acid lactose	134-135	+36 ⟶ +53a2 (c 1, H_2O)

/1/ Includes substances not found free but found in the hydrolyzates of a natural material. Unless otherwise stated, all data are for crystalline substances. /2/ In preparing this table the literature has been covered through 1952. /3/ Aldoses are arranged alphabetically within groups formulated according to increasing carbon content in the parent sugar. Since the substances are listed by their accepted chemical nomenclature, or derivative thereof, the following list of common or trivial names or synonyms is given, with relationship to listing in the table, to facilitate location of a substance: apiose (see α-glyceraldehyde), chinovose (see α-glucose), chondrosamine (see α-galactose), cymarose (see α-allose), digitose (see α-galactose), digitalose (see α-allose), digitoxose (see α-allose), eplhamnose (see α-glucose), α-fucose (see α-galactose), L-fucose (see L-galactose), galactosamine (see α-galactose), glucosamine (see α-glucose), hamamelose (see α-Ribose), isorhamnose (see α-glucose), isorhodeose (see α-glucose), olendrose (see L-glucose), quinovose (see α-glucose), L-rhamnose (see L-mannose), sarmentose (see α-gulose), streptose (see L-lyxose), thretose (see α- and L-glucose), vaccinin (see α-glucose). /4/ Unless otherwise stated, the specific rotations are taken in water at concentrations of 5 g or less per 100 ml of solution and at 20-25°C. Other temperatures or wave lengths are shown in brackets. c = g solute per 100 ml solution. /5/ The rotation given is taken from inference to the enantiomorph or D isomer. /6/ The designations for the α and β prime of these compounds are reversed from those of the original authors, in accordance with modern terminology and Hudson's rules of rotation. /7/ Since the ethers and ethers of L-Lyxose are unknown the derivatives of unnatural p-Lyxose are given for reference. /8/ Some question exists on the presence of this material in nature. /9/ This substance is included because of the speculations concerning it in biological processes. /10/ This structure for sarmentose is postulated but not proved in reference. /11/ Passes through a minimum in mutarotating.

Part II: NATURAL MONOSACCHARIDES: KETOSES[1,2]

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
1	Triulose (dihydroxyacetone) ($C_3H_6O_3$)	80 (dimer)	None
2	Dihydroxyacetone p-nitro phenylhydrazone	160	
3	Dihydroxyacetone oxime	84	
4	Dihydroxazone bis(2,4-dinitrophenylhydrazone)		
5	Dihydroxyacetone diacetate	46-47	
6	L-Glycero-tetrulose[5] (L-erythrosulose)(keteerythritol) (L-tetrulose) ($C_4H_8O_4$)	Sirup	+12
7	L-Erythrulose, O-nitro-phenylhydrazone	152-153	+48 [18°] (c 1, C_2H_5OH)
8	p-Erythro-pentulose (adonose) (p-ribulose) ($C_5H_{10}O_5$)	Sirup	+16.6[27°]
9	1,3,4,5-Di-O-iso-propylidene-p-ribulose (diacetone ribulose)	5	+105.5 [27°] (c 1, CH_3COCH_3)
10	L-Threo-pentulose (L-xylulose) (L-lyxulose)(xylokетose) ($C_5H_{10}O_5$)	Sirup	+33.1
11	L-Xylulose p-bromophenyl-hydrazone	128-129	-26 ⟶ +31.9 (C_6H_5N)
12	β-p-Arabo-hexulose (β-p-fructose)(levulose) ($C_6H_{12}O_6$)	102-104	-133.5 ⟶ -92
13	α-Fructose p-nitro phenyl-hydrazone	176	
14	α-Fructose oxime	118	
15	1, 3, 4, 5-Tetra-O-acetyl-β-p-fructopyranose	131-132	-91.6 (c 3, $CHCl_3$)
16	1, 3, 4, 5, 6-Penta-O-acetyl-α-fructose	70	+34.7 (c 8, $CHCl_3$)
17	Penta-O-acetyl-β-α-fructo-pyranose	108-109	-120.9 (c 5, $CHCl_3$)
18	Methyl α-α-fructofuranoside	69, 81	+93 (c 2, H_2O)
19	Methyl β-α-fructofuranoside	Sirup	-50 (c 1, H_2O)
20	Methyl α-α-fructopyranoside	96-97	+44 (c 1, H_2O)
21	Methyl β-α-fructopyranoside	119-120	-172.1 (c 10, H_2O)
22	1-O-Methyl-α-fructose	Sirup	-49.8 (c 2.2, CH_3OH)
23	Methyl 3-O-methyl-α-fructoside	143	-34.6 (c 1.1, C_2H_5OH)
24	3-O-Methyl-α-fructose	122-123	-70.5 ⟶ -53.1 (H_2O)
25	β-α-Arabo-hexulose (β-α-fructose)(levulose) ($C_6H_{12}O_6$) (concluded)	Sirup	-87.5 (c 0.4, H_2O)
26	6-O-Methyl-α-fructose	Sirup	+6.4 (c 1.2, 0.06N HCl)
27	3, 4-Di-O-methyl-α-fructose	Sirup	-60.7 (c 0.8, H_2O)
28	Methyl 1, 3, 4-tri-O-methyl-α-fructoside	Sirup	+57.3 (c 1, H_2O)
29	1, 3, 4-Tri-O-methyl-α-fructose	73	-23.8 ⟶ +51.8 (c 8, H_2O)
30	1, 4, 6-Tri-O-methyl-α-fructose	Sirup	+30.3 (H_2O)
31	3, 4, 5-Tri-O-methyl-α-fructose	Sirup	-115.9 (H_2O)
32	3, 4, 6-Tri-O-methyl-α-fructose	Sirup	+20.4, +25.6 [16°] (c 1, $CHCl_3$)
33	Methyl 1, 3, 4, 5-tetra-O-methyl-β-α-fructo-pyranoside	33-34	-149.8 (c 3, H_2O)
34	1, 3, 4, 5-Tetra-O-methyl-α-fructose	98-99	-124.7 ⟶ -121.3 (c 5, H_2O)
35	Methyl 1, 3, 4, 6-tetra-O-methyl-α-α-fructofuranoside	Sirup	+129.4 (c 2.6, H_2O)
36	1, 3, 4, 6-Tetra-O-methyl-α-fructose	Sirup	+31.3 [16°] (c 2, H_2O)
37	1, 3, 4, 6-Tetra-O-methyl-α-"fructofuranamide"	99-100	-76 [16°] (c 1, H_2O)
38	α-Lyxo-hexulose (α-tagatose) ($C_6H_{12}O_6$)	131-132	+2.7 ⟶ -4.5
39	"Tagaturonic" acid	106-108	-12.5 (c 1.6, H_2O)
40	Penta-O-acetyl-α-tagato-pyranose	132	+30.2 [578] (c 4, $CHCl_3$)
41	Methyl α-α-tagatopyranose	128	+56.8 [578] (c 2, CH_3OH)
42	Methyl tetra-O-methyl-α-α-tagato-pyranoside	Sirup	+21.4 [578] (c 2, CH_3OH)
43	Methyl tetra-O-methyl-α-tagalo side	Sirup	+9.7 [578] (c 2, CH_3OH)
44	Tetra-O-methyl-α-tagato-pyranose	Sirup	-3.4 [578] (c 2, CH_3OH)
45	α-Ribo-hexulose (α-psicose) ($C_6H_{12}O_6$)	Amorp.	+4.7
46	Penta-O-acetyl-keto-α-psicose	63-65	-21.5 [29°] (c 3, $CHCl_3$)
47	Methyl tetra-O-methyl-α-psicopyranoside	Sirup	+36 butated in (HCl, CH_3OH)
48	Di-O-isopropylidene-α-psicose	57-58.5	-98.2 (c 2, CH_3COCH_3)
49	L-Xylo-hexulose (L-sorbose) ($C_6H_{12}O_6$)	159-161	-43.1
50	Di-O-isopropylidoce-L-sorbose	155-157	+44.9 (c 1, CH_3COCH_3)
51	Penta-O-acetyl-keto-L-sorbose	99	+2.4 [578]
52	Tetra-O-acetyl-L-sorbo-pyranose	100.8	-21.3 (c 1.3, $CHCl_3$)
53	Penta-O-acetyl-α-L-sorbo-pyranose	97	-56.5 (c 1.3, $CHCl_3$)
54	Penta-O-acetyl-β-L-sorbo-pyranose	113.8	+74.6 (c 1.3, $CHCl_3$)
55	Methyl tetra-O-methyl-L-sorbofuranoside	Sirup	-39.4 (c 1, $CHCl_3$)
56	Tetra-O-methyl-L-sorbo-furanose	Sirup	+29.7 (c 1, $CHCl_3$)
57	Methyl α-L-sorbopyranoside	120-122	-88.9 (c 8, H_2O)
58	Methyl β-L-sorbopyranoside	106.2	+39 (c 1.7, H_2O)
59	1, 4, 6-Tri-O-methyl-L-sorbofuranose	Sirup	+3.8 (c 1.5, $CHCl_3$)
60	Methyl tetra-O-methyl-α-L-sorbopyranoside	Sirup	-46.2 [578] (c 2, $CHCl_3$)
61	Methyl tetra-O-methyl-β-L-sorbopyranoside	Sirup	+69.8 (c 1, $CHCl_3$)
62	1, 3, 4, 5-Tetra-O-methyl-L-sorbose	Sirup	-15.1 [578] (c 2, $CHCl_3$)
63	4-O-Methyl-L-sorbose	133	-30.9 [16°] (c 2, H_2O)
64	p-Altro-heptulose (α-sedoheptulose) (sedoheptose) ($C_7H_{14}O_7$)	Amorph.	+2.5 (c 10)
65	α-Sedoheptitol (volemitol) (α-glycero-α-manno-heptitol)(α-manno-α-taloheptitol)(α-altro-α-mannoheptitol)	152	+2.3 (c 9, H_2O)

Part II: NATURAL MONOSACCHARIDES: KETOSES[1,2] (Concluded)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
66	D-Altro-heptulose (D-sedoheptulose)(sedoheptose)($C_7H_{14}O_7$) (conedulite) β-Sedoheptitol (D-glycero-D-gluco-heptitol)(L-gluto-α-talo-heptitol)(D-altro-β-gluco-heptitol)	127-128	
67	Sedoheptulosan	155	-146 (c 9, H_2O)
68	L-Gala-heptulose hemihydrate (L-perseulose)($C_7H_{14}O_7 \cdot \frac{1}{2} H_2O$)	110-115	-90 ⟶ -80
69	D-Perseitol (D-manno-D-gala-heptitol, α-mannoheptitol, D-glycero-α-galaheptitol)	187	-1.2 (c 5.5, H_2O)
70	L-Gala-α-glucoheptitol (L-glycero-D-glucoheptitol, L-glycero-α-galaheptitol)	141	-2.4 (c 4, H_2O)
71	Hexa-O-acetyl-keto-L-perseulose	105	+0.57 [578] (c 4, $CHCl_3$)
72	Hexa-O-acetyl-L-perseulose	112	-113 [578] (c 1, $CHCl_3$)
73	D-Manno-heptulose (mannoketoheptose)(D-manno-α-tagato-heptose) ($C_7H_{14}O_7$)	152	+29.4
74	D-Manno-heptulose p-bromo-phenylhydrazone	179	
75	D-Perseitol and volemitol (See Lines 69 and 65 above)		
76	D-Manno-heptulose hexa-acetate	110	+39 (c 2, $CHCl_3$)

[1] Includes substances not found free but found in the hydrolyzates of a natural material. Also included are some substances which are bacterial oxidation products of a natural material. Unless otherwise stated, all data are for crystalline substances. [2] In preparing this table the literature has been covered through 1952. [3] Ketoses are arranged alphabetically within groups formulated according to increasing carbon content in the parent sugar. Since the substances are listed under their systematic name in carbohydrate nomenclature the following list of common names and synonyms is given to facilitate the location: adonose (see D-erythro-pentulose), D-allulose (see D-ribo-hexulose), dihydroxyacetone (see triulose), L-erythrulose (see D-glycero-tetrulose), D-fructose (see D-arabo-hexulose), levulose (see D-arabo-hexulose), L-lyxulose (see L-threo-pentulose), perseulose (see L-gala-heptulose), D-psicose (see D-ribo-hexulose), D-ribulose (see D-erythro-pentulose), D-sedoheptulose (see D-altro-heptulose), L-sorbose (see L-xylo-hexulose), D-tagatose (see D-lyxo-hexulose), L-threulose (see L-glycero-tetrulose), volemose (see D-altro-heptulose), L-xylulose (see L-threo-pentulose), xylosetose (see L-threo-pentulose). [4] Unless otherwise stated, the specific rotations are taken in water at concentrations of 5 g or less per 100 ml of solution and at 20-25°C. Other temperatures or wave lengths are shown in brackets; c = g solute per 100 ml of solution. [5] Some of the early literature names this substance D-erythrulose.

Part III: NATURAL OLIGOSACCHARIDES[1,2]

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
1	O-α-D-Mannopyranosyl-(1→6)-D-glyceric acid ($C_9H_{16}O_9$)	88-89	+105 [15°]
2	Sodium salt	270 d.	
3	2-O-α-D-Galactopyranosyl-glycerol ($C_9H_{18}O_8$)	86-87	+151
4	Galactinol dihydrate (1-O-α-D-galactopyranosyl-myo-inositol dihydrate) $6C_{12}H_{22}O_{11} \cdot 2H_2O$)	220-222	+135.6
5	Galactinol nonamethyl ether	96.5-98	+119 (c 2, H_2O)
6	Primeverose (6-O-β-D-xylopyranosyl-D-glucose) ($C_{11}H_{20}O_{11}$)	208	+24.1 ⟶ +3.3
7	Primeverose heptaacetate	216	-23.5 ($CHCl_3$)
8	Vicianose (6-O-α-L-arabinopyranosyl-D-glucose ($C_{11}H_{20}O_{10}$)	210	+56.6 ⟶ +40.5 [14°]
9	Vicianose heptaacetate	158-160	+6.5 [14°] ($CHCl_3$)
10	D-Xylopyranosyl-D-glucopyranoside[5] ($C_{11}H_{20}O_{10}$)	Amorph.	-36.5
11	D-Xylopyranosyl-D-glucopyranoside dibenzoate	147-148	-106.7 (c 2, CH_3OH)
12	D-Xylopyranosyl-D-glucopyranoside pentaacetate dibenzoate	203	
13	iso-D-Xylosyl-D-glucoside dibenzoate	173-174	-6.3 (c 0.8, CH_3OH)
14	Allolactose (6-O-β-D-galactopyranosyl-D-glucose) ($C_{12}H_{22}O_{11}$)	165	+25
15	Allolactose octaacetate	166	
16	Amylolyose (3-O-β-D-glucopyranosyl-D-glucose) ($C_{12}H_{22}O_{11}$)		+59.3 ⟶ +46.4 [15°] (CH_3OH)
17	β-Cellobiose (4-O-β-D-glucopyranosyl-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	225	+14.2 ⟶ +34.6 (c 8)
18	β-Maltose monohydrate ($C_{12}H_{22}O_{11} \cdot H_2O$)	102-103	+112.5 ⟶ +130
19	β-Maltose octaacetate	159-160	+62.6 (c 5, $CHCl_3$)
20	4-O-β-D-Manno pyranosyl-β-D-mannopyranose ($C_{12}H_{22}O_{11}$)	193-194	-7.7 ⟶ +2.2
21	β-Melibiose dihydrate (6-O-α-D-galactopyranosyl-β-D-glucopyranose) ($C_{12}H_{22}O_{11} \cdot 2H_2O$)	82-85	+111.7 ⟶ +129.5
22	β-Melibiose octaacetate	177	+102.5
23	Robinobiose (6-O-β-L-rhamnopyranosyl-D-galactopyranose) ($C_{12}H_{22}O_{10}$)	Amorph.	+2.72 ⟶ 0
24	Robinobiose heptaacetate	113, 84-85 (amorph.	-19.23, -9.9 ($CHCl_3$)
25	Methyl β-robinobioside hexaacetate	159-160	-39.6 ($CHCl_3$)
26	Rutinose (6-O-β-L-rhamnopyranosyl-D-glucopyranose) ($C_{12}H_{22}O_{10}$)	189-192 d. amorph.	+3.2 ⟶ -0.8 [16°]
27	Rutinose heptaacetate	168-169	-29.7 ($CHCl_3$)
28	Scillabiose (4-O-β-D-glucopyranosyl-L-rhamnopyranose) ($C_{12}H_{22}O_{10}$)	Amorph.	-24.8
29	Scillabiose hexaacetate	97	
30	α-Sophorose monohydrate (2-O-β-D-glucopyranosyl-α-D-glucopyranose) ($C_{12}H_{22}O_{11} \cdot H_2O$)	195-196	+32 ⟶ +18
31	α-Sophorose octaacetate	111	+45 (c 1, $CHCl_3$)
32	β-Sophorose octaacetate	192	-2.8 (c 10, $CHCl_3$)
33	Sucrose (β-D-fructofuranosyl-α-D-glucopyranoside) ($C_{12}H_{22}O_{11}$)	188, 170[5]	+66.5 (c 26)
34	D-α-Mannopyranosyl-(1→6)-D-α-mannopyranosyl-(1→6)-D-α-glucopyranose (levidulinose?) ($C_{18}H_{32}O_{16}$)	217	-16, -15.3, -11.6
35	6-[6-(Mannopyranosyl)-mannopyranosyl]-glucopyranose hendecaacetate	95-110	+18
36	Melezitose dihydrate (O-α-D-glucopyranosyl-(1→3)-O-β-D-fructofuranosyl-(2→1)-α-D-glucopyranoside)($C_{18}H_{32}O_{16} \cdot 2H_2O$)	153-154	+88.2
37	Melezitose hendecaacetate	117	+103.6 (c 1, $CHCl_3$)
38	Planteose dihydrate (O-α-D-galactopyranosyl-(1→6)-O-β-D-fructofuranosyl-(1→6)-O-α-D-glucopyranoside) ($C_{18}H_{32}O_{16} \cdot 2H_2O$)	123-124	+125.2
39	Planteose hendecaacetate	135	+97 (c 1, CH_3OH)
40	Raffinose pentahydrate (O-α-D-galactopyranosyl-(1→6)-O-α-D-glucopyranosyl-(1→2)-O-β-D-fructofuranoside) ($C_{18}H_{32}O_{16} \cdot 5H_2O$)	80, 118-120	+105, +123.1
41	Raffinose hendecaacetate	99-101	+92.2, +100.3 (c 8, C_2H_5OH)
42	Rhamninose ($C_{18}H_{32}O_{14}$) amorph.	135-140 d.	+41.0
43	Rhamninose octaacetate (?)	95-100 amorph.	-30.9 (C_2H_5OH)
44	Robinose[7] ($C_{18}H_{32}O_{14}$) amorph.	260	+5.2 ⟶ +1.9
45	Scorodose ($C_{18}H_{32}O_{21}$) amorph.	85-90	+41.5
46	Acetyl scorodose		-28.5 (c 5.4, $CHCl_3$)

18	α-Cellobiose octaacetate	229	+41.0 (c 6, $CHCl_3$)
19	β-Cellobiose octaacetate	202	-14.7 (c 5, $CHCl_3$)
20	α-Gentiobiose ($C_{12}H_{22}O_{11}\cdot 2CH_3OH$)	85-86	+31 ⟶ +9.6
21	α-Gentiobiose octaacetate	189	+52.4 (c 4, $CHCl_3$)
22	β-Gentiobiose (6-O-β-D-glucopyranosyl-β-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	190	-3.0 ⟶ +10.5
23	β-Gentiobiose octaacetate	193	-5.4 (c 6, $CHCl_3$)
24	Gynolactose ($C_{12}H_{22}O_{11}$)	205	-27
25	Isomaltose (6-O-α-Glucopyranosyl-β-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	Amorph.	+103.2, +122
26	β-Isomaltose octaacetate	144-145	+96.9 (c 2.7, $CHCl_3$)
27	α-Lactose monohydrate ($C_{12}H_{22}O_{11}\cdot H_2O$)	202	+83.5 ⟶ +52.6
28	α-Lactose octaacetate	152	+53.6 (c 10, $CHCl_3$)
29	β-Lactose (4-O-β-D-galactopyranosyl-β-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	252	+34.2 ⟶ +53.6
30	β-Lactose octaacetate	90	-4.7 (c 10, $CHCl_3$)
31	Laminaribiose (3-O-β-D-glucopyranosyl-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	160-163	+20.8 ⟶ +16.1, +23.4 ⟶ +19
32		188-192	+7.5 ⟶ +20.8
33	α-Laminaribiose octaacetate monoethanolate	77-78	+20 (c 3.6, $CHCl_3$)
34	β-Laminaribiose octaacetate	160-161	-28.8 (c 2.5, $CHCl_3$)
35	α-Maltose (4-O-α-D-glucopyranosyl-α-D-glucopyranose) ($C_{12}H_{22}O_{11}$)	108	+173
36	α-Maltose octaacetate	125	+122.8 (c 5, $CHCl_3$)
53	Sucrose octaacetate	69, 75[6]	+59.6 ($CHCl_3$)
54	Trehalose dihydrate ($C_{12}H_{22}O_{11}\cdot 2H_2O$)	97	+178.3 (c 7)
55	Trehalose (α-D-glucopyranosyl-α-D-glucopyranoside ($C_{12}H_{22}O_{11}$)	203	
56	Trehalose octaacetate	98	+162.3 (c 10, $CHCl_3$)
57	Turanose (3-O-α-D-glucopyranosyl-D-fructopyranose) ($C_{12}H_{22}O_{11}$)	157	+22 ⟶ +75.3
58	Turanose octaacetate, I	216-217	+20.5 (c 4, $CHCl_3$)
59	Turanose octaacetate, II	158	+107 (c 1, $CHCl_3$)
60	Turanose octaacetate, III (keto form)	96	+126.2 (c 6, $CHCl_3$)
61	Turanose octaacetate, IV	194-195	+103.2 (c 3, $CHCl_3$)
62	Gentianose (O-β-D-glucopyranosyl-(1 ⟶ 6)-O-α-D-glucopyranosyl-(1 ⟶ 2)-β-D-fructofuranoside) ($C_{18}H_{32}O_{16}$)	210	+33.4
63	Lahlose trihydrate ($C_{18}H_{32}O_{16}\cdot 3H_2O$)	BP 205 (126 a.)	+136.7
64	Lahlose hendecaacetate	88	+122.5 ($CHCl_3$)
65	Maltotriose (O-α-D-glucopyranosyl-(1 ⟶ 4)-O-α-D-glucopyranosyl-(1 ⟶ 4)-D-α-glucopyranose) ($C_{18}H_{32}O_{16}$)	150 amorph.	+160
66	β-Maltotriose hendecaacetate	134-136	+86 (c 1.6, $CHCl_3$)
67	Manninotriose (O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-galactopyranosyl-(1 ⟶ 6)-α-D-glucopyranose) ($C_{18}H_{32}O_{16}$)	Amorph.	+167
68	Manninotriose hendecaacetate	(105 a.)	+135 (C_2H_5OH)
82	Stachyose (manneotetrose) (O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-galactopyranosyl-(1 ⟶ 2)-O-β-D-fructofuranoside) ($C_{24}H_{42}O_{21}$)	170 (140 a.)	+146.3
83	Stachyose tetradecaacetate	95-96 amorph.	+120.2 (C_2H_5OH)
84	Verbascose (O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-galactopyranosyl-(1 ⟶ 6)-O-α-D-glucopyranosyl-(1 ⟶ 2)-O-β-D-fructofuranoside($C_{30}H_{52}O_{26}$)	219-220, 253	+169.9
85	Verbascose heptadecaacetate	132	+130.4
86	Hexasaccharide (cyclic oligosaccharide) ($C_{36}H_{60}O_{30}\cdot 12H_2O$)	290-300	+151.8
87	Octadeca-O-Methyl-hexasaccharide (cyclic)	98-103	+160.5
88	Schardinger-α-dextrin (cyclohexamylose) ($C_{36}H_{60}O_{30}$)		+150.6
89	α-Dextrin acetate		+105.5 (c 1, $CHCl_3$)
90	Schardinger-β-dextrin (cycloheptamylose) ($C_{42}H_{68}O_{34}$)		+162.5
91	β-Dextrin acetate	196-196.5	+125.5
92	Schardinger-γ-dextrin (cyclooctaamylose) ($C_{48}H_{72}O_{38}$)		+177.4
93	γ-Dextrin acetate		+138.5 (c 1, $CHCl_3$)

/1/ This table is limited to those oligosaccharides which exist free, or as simple derivatives, in nature or which may be derived from a larger oligosaccharide or a polysaccharide by means of enzymic action. /2/ In preparing this table the literature has been covered through 1952, and partially through 1953. Unless otherwise noted, all data are for crystalline materials. /3/ The substances are arranged alphabetically within groups which are formulated according to increasing carbon content. /4/ Unless otherwise stated, the rotations are taken in water at concentrations less than 5 and at temperatures of 20-25°C. Other temperatures are shown in brackets; c = grams solute per 100 ml of solution. /5/ The free sugar does not exist in nature but the dibenzoyl derivatives do. /6/ The compound crystallizes in one of two forms, depending on the solvent used. /7/ This substance may be robinobiose.

Part IV: NATURAL *ALDITOLS* AND *INOSITOLS*[1]

	Substance[2]	MP °C	$[\alpha]_D$, degrees[3]
1	Glycerol ($C_3H_8O_3$)	20	None
2	Glycerol tribenzoate	76	None
3	Glycerol, α-deoxy- (1, 2-propanediol[5] ($C_3H_8O_2$)	Oil, BP 188-189	(Racemic) none
4	1, 2-Propanediol distearate	72-73	None
5	Erythritol ($C_4H_{10}O_4$)	118-120	(Meso), none
6	Erythritol tetraacetate	85	None
7	Erythritol, 1, 4-dideoxy- (2, 3-butyleneglycol)($C_4H_{10}O_2$)	25, 34	(Meso), none
8	1, 4-Dideoxy-erythritol pentahydrate	16.8	
9	2, 3-Butyleneglycol diphenylurethane	196	
10	2, 3-Butyleneglycol dibenzoate	77	
11	D-Threitol, 1, 4-dideoxy-($C_4H_{10}O_2$)	19	-13.0
12	1, 4-Dideoxy-D-threitol diacetate	Sirup BP 192-194/745 mm	+1.4
13	L-Threitol, 1, 4-dideoxy-($C_4H_{10}O_2$)		+10.2
14	D, L-Threitol, 1, 4-dideoxy-($C_4H_{10}O_2$)	7.6	None
15	1, 4-Dideoxy-D, L-threitol diacetate	41-41.5	
16	1, 4-Dideoxy-D, L-threitol dibenzoate	53-54	
17	D-Arabitol ($C_5H_{12}O_5$)	103	+7.82 (c 8, borax soln.)
18	D-Arabitol pentacetate	76	+37.2 ($CHCl_3$)
19	Ribitol (adonitol) ($C_5H_{12}O_5$)	102	(Meso), none
20	Ribitol pentacetate	51	
21	Galactitol (dulcitol) ($C_6H_{14}O_6$)	186-188	(Meso), none
22	Galactitol hexacetate	168-169	
23	L-Iditol ($C_6H_{14}O_6$)	73.5	-3.5 (c 10)
24	L-Iditol hexacetate	121.5	-25.7 (c 5, $CHCl_3$)
25	D-Mannitol ($C_6H_{14}O_6$)	166	-0.21
26	D-Mannitol hexacetate	126	+18.8 (CH_3COOH)
27	D-Mannitol, 1, 5-anhydro-(styracitol) ($C_6H_{12}O_5$)	157	-49.9
28	Styracitol tetracetate	66-67	-20.9 (C_2H_5OH)

Part IV: NATURAL ALDITOLS AND INOSITOLS (Concluded)

	Substance[3]	MP °C	$[\alpha]_D$, degrees[4]
29	Sorbitol (D-glucitol) ($C_6H_{14}O_6$)	112	-1.8 [15°]
30	Sorbitol hexaacetate	99	+12.5 (c 0.8, $CHCl_3$)
31	Sorbitol, 1, 5-anhydro- (polygalitol) ($C_6H_{12}O_5$)	140-141	+42.4
32	Polygalitol tetraacetate	73-74	+38.9 (c 2, $CHCl_3$)
33	D-Perseitol (D-manno-D-gala-heptitol) (D-gala-D-glycero-heptitol) ($C_7H_{16}O_7$)	188	-1.1
34	D-Perseitol heptaacetate	119	-13.3 ($CHCl_3$)
35	D-Volemitol (D-manno-D-talo-heptitol) (D-talo-D-glycero-heptitol) ($C_7H_{16}O_7$)	153	+2.65
36	D-Volemitol heptaacetate	62	+36.1 (c 2, $CHCl_3$)
37	Betitol (a dideoxy inositol) ($C_6H_{12}O_4$)	224	
38	Bioinosose (acyllo-meso-inosose) (inosose) ($C_6H_{10}O_6$)	198-200	
39	Inosose phenylhydrazone	220-222	
40	Inosose pentaacetate	106-108	
41	Bornesitol (meso-inositol monomethyl ether) ($C_7H_{14}O_6$)	200	+31.6
42	Conduritol (2, 3-dehydro-2, 3-di-deoxy-D-inositol) ($C_6H_{10}O_4$)	142-143	None
43	Conduritol dibromide	176	
44	Conduritol tetraacetate	BP 165° at 0.6 mm	
45	Dihydroconduritol	204	
46	Dambonitol (meso-inositol dimethyl ether) ($C_8H_{16}O_6$)	206	None
47	Dambonitol tetraacetate	195	
48	meso-Inositol (myo-inositol) ($C_6H_{12}O_6$)	217-218	None
49	meso-Inositol hexaacetate	211-212	
50	meso-Inositol monophosphate	190-191 d.	
51	meso-Inositol monophosphate brucine salt[5]	236-238	
52	meso-Inositol hexaphosphate dodeca-sodium salt +38 H_2O[6]	58-59	
53	meso-Inositol tetraphosphate[7]		-3.9 (H_2O) [14.5°]
54	meso-Inositol tri-phosphate[7]		-8.3 (H_2O) [15°]
55	meso-Inositol diphosphate[7]		-6.0 (H_2O)
56	m-Inositol ($C_6H_{12}O_6$)	253	None
57	m-Inositol hexaacetate	111	
58	Mytilitol (c-methyl-acyllitol) ($C_7H_{14}O_6$)	259	(Meso), none
59	Mytilitol pentaacetate	157-158	
60	Mytilitol hexaacetate	180-181	
61	Pinitol (o-inositol monomethyl ether) ($C_7H_{14}O_6$)	186	+65.5
62	Pinitol pentaacetate	98	+8.6 (c 2, C_2H_5OH)
63	Quebrachitol (L-inositol monomethyl ether) ($C_7H_{14}O_6$)	190-191	-80.2° [28°]
64	Quebrachitol pentaacetate	96-97	-25.1 [29°] (c 4, $CHCl_3$)
65	D-Quercitol (deoxy-D-inositol) ($C_6H_{12}O_5$)	235	+24.2
66	D-Quercitol pentaacetate		
67	L-Quercitol (deoxy-L-inositol)[8] ($C_6H_{12}O_5$)	174	-73.9
68	L-Quercitol pentaacetate	124-125	-26.0 (c 2.7, $CHCl_3$)
69	D-Quinic acid (2, 3, 4-trideoxy-3-carboxy-D-inositol) ($C_7H_{12}O_6$)	164	+44 (c 10)
70	L-Quinic acid ($C_7H_{12}O_6$)	162	-42.1
71	L-Quinic acid lactone triacetate (form 1)	132	
72	L-Quinic acid lactone triacetate (form 2)	139	
73	L-Quinic acid tetraacetate	130-136	-22.5 (c 5, C_2H_5OH)
74	m-Quinic acid		None
75	Scyllitol (econsitol) ($C_6H_{12}O_6$)	352-353	None
76	Scyllitol hexaacetate	299-300	None
77	Streptidine (1, 3-dideoxy-1, 3-diguanidino-scyllitol) ($C_8H_{18}N_6O_4$)		None
78	Di-N-acetyl-tetra-O-acetyl-streptamine	342-345	None
79	N, N'-Diacetylstreptamine	383-384	None
80	Streptamine hemihydrate (1, 3-diamino-1, 3-dideoxy scyllitol)	205 a.	None
81	Streptidine dipicrate	284-285 d.	None
82	Sequoyitol (meso-inositol monomethyl ether) ($C_7H_{14}O_6$)	234-235 [28°]	(Meso), none
83	Sequoyitol pentaacetate	198	
84	Shikimic acid (3, 4-dehydro-quinic acid) ($C_7H_{10}O_5$)	183-184	-200 [16°]
85	Methyl shikimate	113-114	None
86	Shikimic acid triacetate	BP 0.1 200-210	

/1/ This table contains the alditols and inositols which occur in nature, free or as hydrolytic products from natural substances. Naturally occurring simple derivatives of these polyols are also included. The literature has been covered through 1952 and partially through 1953. Unless otherwise noted all data are for crystalline materials. /2/ The alditols are all listed first, arranged alphabetically in groups which are formulated according to increasing carbon content in the parent compound. The inositols are then listed similarly. /3/ Unless otherwise stated the rotations are taken in water at concentrations less than 5 and at temperatures of 20-25° C. Other temperatures are shown in brackets; c = grams solute per 100 ml of solution. /4/ The l-phosphate ester of this diol is said to occur in brain tissue and sea urchin eggs. /5/ Found as a hydrolysate product of lipositol. /6/ Prepared from natural phytin, the calcium and magnesium salt of phytic acid or meso-inositol hexaphosphate. /7/ Obtained by enzyme action on meso-inositol hexaphosphate. /8/ This is not an enantiomorph of a D-quercitol. Other isomeric relationship is involved.

Part V: NATURAL ALDONIC, URONIC, AND ALDARIC ACIDS[1]

	Substance[2]	MP °C	$[\alpha]_D$, degrees[3]
1	D-Glyceric acid ($C_3H_6O_4$)	Gum	Dextro
2	Methyl D-glycerate	Sirup BP 4.8 119/14 mm	
3	Methyl 2, 3-di-O-methyl-D-glycerate	Sirup BP 69.7 77/15 mm	
4	D-Glyceronamide	99.5-100	-63.1 (c 2.4, CH_3OH)
5	2, 3-Di-O-methyl-D-glyceronamide	77-77.5	-54.5 (c 3.1, CH_3OH)
6	D-Glyceric acid, brucine salt	222	+33.2
7	L-Glyceric acid ($C_3H_6O_4$)	Gum	Levo
8	Calcium L-glycerate dihydrate	134-135	-12 [30°]
9	D-Arabonic acid ($C_5H_{10}O_6$)	114-116	10.5 (c 6)
10	D-Arabono-γ-lactone (See also L-arabonic acid)	96	73.7
11	D-Gluconic acid, 2-deoxy-2-keto"- ($C_6H_{10}O_7$) (concluded)		
39	Methyl tetra-O-acetyl-2-deoxy-2-"keto"-D-gluconate	168-169	-133 (c 2, $CHCl_3$)
40	D-Gluconic acid", 5-deoxy-5-"keto"- ($C_6H_{10}O_7$)		-14.5
41	5-Deoxy-5-"keto"-D-gluconic acid phenylosazone	110-130 variable	
42	5-Deoxy-5-"keto"-D-gluconic acid p-nitrophenylhydrazone	190-212 variable	
43	D-Mannonic acid ($C_6H_{12}O_7$)		15.6
44	D-Mannono-γ-lactone	151	51.8 ⟶ 47
45	D-Mannono-γ-lactone tetraacetate	119	52 (80% CH_3COCH_3)
46	D-Mannonamide	172-173	-17.3
47	D-Mannono-δ-lactone	161-162	111.9 ⟶ 39.9
48	D-Mannonic phenylhydrazide	214-216	-8.1 [80°]
70	D-Glucuronic acid ($C_6H_{10}O_7$) (concluded)		
71	Methyl (methyl 4-O-methyl-D-glucopyranoside)	Sirup	95 (c 10, H_2O)
72	Methyl 4-O-methyl-D-glucopyranosiduronamide	232	150
73	Methyl 4-O-methyl-D-glucopyranosiduronic acid	Sirup	45 (c 5.8, H_2O)
74	Methyl 2, 3-di-O-methyl-D-glucopyranosiduronic acid	Sirup	68
75	Methyl (methyl 2, 3-di-O-methyl-D-glucopyranoside) uronate	Sirup	76 (c 0.7, H_2O)
76	Methyl 2, 3-di-O-methyl-D-glucopyranosidurono phenylhydrazide	225-227	

11	L-Arsonic acid ($C_6H_{10}O_8$)	118-119	-9.6 ⟶ -41.7[4]	49	α-D-Galacturonic acid monohydrate ($C_6H_{12}O_8$)	159-160 (110-115 a.) 160	97.9 ⟶ 50.9	77	Methyl (methyl 2, 3, 4-tri-O-methyl-α-glucopyranoside) uronate	Sirup	87
12	L-Arabonamide	135-136	37.2					78	Methyl 2, 3, 4-tri-O-methyl-α-glucopyranosiduronamide	183	137.5 (c 0.7, H_2O)
13	L-Arabonic phenylhydrazide	215		50	D-Bromophenylhydrazine salt of D-galacturonic acid p-bromophenylhydrazone	145-146	942 [220] (c 0.7, CH_3OH)	79	α-D-Mannuronic acid monohydrate ($C_6H_{12}O_8$)	(110 a.) 120-130 d.	16.0 ⟶ -6.1 (c 6.8)
14	L-Arabonic acid tetraacetate (See also α-arabonic acid above)	135-135.5	-32 (c 1.5, $CHCl_3$)					80	D-Mannopyranurono-γ-lactone	140-141	89.3
15	D-Ribonic acid ($C_5H_{10}O_6$)	112-113	-17.0	51	β-D-Galacturonic acid ($C_6H_{10}O_7$)	160	27 ⟶ 55.6	81	β-D-Mannuronic acid ($C_6H_{10}O_7$)	165-167	-17.9 ⟶ -23.9
16	D-Ribono-γ-lactone	77		52	D-Galacturonic acid p-bromophenylhydrazone	150-151	11.5α‡ [220] (c 1.36, CH_3OH)	82	D-Mannopyranurono-γ-lactone p-bromophenylhydrazone	160 d.	64.5α‡ (c 2.3, CH_3OH)
17	D-Ribonamide	136-137	16.5					83	D-Bromophenylhydrazine salt of D-mannuronic p-bromophenylhydrazone	143-144 d.	48.5α‡ (c 1.4, CH_3OH)
18	D-Ribonic acid tetraacetate	138-139	-24.4 (c 2.3, $CHCl_3$)	53	Methyl α-D-galacturono-pyranoside dihydrate	113	129.9				
19	D-Xylonic acid ($C_5H_{10}O_6$)		-2.9 ⟶ 20.1[4]	54	Methyl β-D-galacturono-pyranoside monohydrate	134	-39.2	84	D-Bromophenylhydrazide of D-mannuronic p-bromophenylhydrazone	174-175 d.	18.5α‡ (c 0.75 C_5H_5N)
20	D-Xylono-γ-lactone	99-103	85.5 ⟶ 24.2	55	Methyl (methyl-α-D-galacto-pyranoside) uronate monohydrate	142	125.4	85	D, L-Di-O-methyl-α-mannopyranuronic acid	Sirup	30 (c 1.5, CH_3OH)
21	D-Xylonic acid tetraacetate	86-88	-2 (c 2, $CHCl_3$)	56	Methyl (methyl-β-D-galacto-pyranoside) uronate	194	-45.6	86	Methyl (methyl 2, 3-di-O-methyl-α-mannopyranoside) uronate	Sirup	59
22	Cadmium D-xylonate, cadmium bromide double salt dihydrate		8.8	57	2-O-Methyl-α-D-galacto-pyranuronamide	173		87	2, 3, 4-Tri-O-methyl-α-mannopyranuronic acid	Sirup	36.4
23	D-Galacturonic acid ($C_6H_{12}O_7$)	122	-11.2 ⟶ -57.6[4]	58	Methyl (methyl 2-O-methyl-α-D-galactopyranoside) uronate	Sirup	80	88	Methyl (methyl 2, 3, 4-tri-O-methyl-α-mannopyranoside) uronate	Sirup	60 (c 10, H_2O)
24	D-Galactono-γ-lactone	112	-73 ⟶ -63.7	59	Methyl 2-O-methyl-α-α-D-galactopyranosiduronamide	174	55 (c 0.05, CH_3OH)	89	2, 3, 4-Tri-O-methyl-α-mannosaccharodiamide	228	-17 (c 0.5, CH_3OH)
25	D-Galactonamide	172-172.5	30.2	60	Methyl 2, 3-di-O-methyl-β-α-galactofuranosiduronamide	122	-146 [16°]	90	D-Tartaric acid ($C_4H_6O_6$)	170	-15
26	D-Galactonic phenylhydrazide	203	10.4	61	2, 3-D-O-methyl-α-D-galacto-pyranuronic acid	Sirup	62 [14°]		See L-tartaric acid		
27	D-Galactonic acid pentaacetate	131-132	12 (c 3, $CHCl_3$)	62	Methyl (methyl 2, 3-di-O-methyl-β-galactopyranoside) uronate	Sirup	7	91	L-Tartaric acid ($C_4H_6O_6$)	170	15 [15°]
28	D-Galactonic acid, 2-deoxy-2-"keto"- ($C_6H_{10}O_7$)	169	-5	63	2, 3, 4-Tri-O-methyl-α-α-galacturonic acid monohydrate	98-99	120 ⟶ 104	92	L-Tartaric acid diacetate tribydrate	58	-19.32
29	2-Deoxy-2-"keto"-α-galactonic acid, brucine salt	172	-22.5 (50% C_2H_5OH)	64	Methyl (methyl 2, 3, 4-tri-O-methyl-α-galactopyranoside)-uronate	70	149.0 (c 1.2, CH_3COCH_3)	93	Dimethyl L-tartrate	48, 61.5	2.74
30	D-Gluconic acid ($C_6H_{12}O_7$)	130-132 (110-112 a.)	-6.7 ⟶ 11.9[4]					94	L-Tartaramide	195	106.5
31	D-Glucono-γ-lactone	134-136	67.5 ⟶ 17.7	65	D-α-Glucuronic acid ($C_6H_{10}O_7$)	156	11.7 ⟶ 36.3	95	L-Malic acid ($C_4H_6O_5$)	100	-2.3 (c 8.4)
32	D-Gluconamide	143-144	31.2	66	D-Glucopyranurono-γ-lactone	180	18.6				
33	D-Gluconic phenylhydrazide	200	12	67	α-D-Glucopyranurono-γ-lactone triacetate	110-112	203.6 (c 0.9, $CHCl_3$)				
34	D-Glucono-δ-lactone	150-152	61.7 ⟶ 6.2	68	β-D-Glucopyranurono-γ-lactone triacetate	194-195	84.1 (c 1.5, $CHCl_3$)	96	Malic acid acetate	132	
35	D-Gluconic acid pentaacetate	110-111	11.5 (c 2, $CHCl_3$)	69	Phenylhydrazide of α-glucuronic phenylhydrazone	182		97	Dimethyl malate	Sirup BP_{11} 129	-6.84
36	D-Gluconic acid, 2-deoxy-2-"keto"- ($C_6H_{10}O_7$)		-81.7 (sodium salt)					98	Malamide	156-157	-37.9
37	Methyl 2-deoxy-2-"keto"-α-gluconate	173	-82.1 ⟶ -77.4								
38	2-Deoxy-2-"keto"-α-glucono-γ-lactone triacetate	154	-60.4 (c 2.2, $CHCl_3$)								

/1/ This table contains those sugar acids which are found free, as components in hydrolyzates of natural products, or as oxidation products of bacterial action on some natural monosaccharide or aldiitol. The literature has been covered through 1952 and partially through 1953. Unless otherwise stated, all data are for crystalline substances. /2/ The aldonic acids are listed first, arranged alphabetically in groups which are formulated according to increasing carbon content in the parent sugar. Then uronic acids, and finally, glycaric acids are similarly listed. It is to be noted that while acetate derivatives are given for a few of the aldonic acids not all of such derivatives have been made directly from the parent free acid. Since some have, however, the acetates listed have been given as a matter of completeness. /3/ Unless otherwise stated, the rotations are taken in water at concentrations less than 5 and at 20-25° C. Other temperatures are shown in brackets; c = grams of solute per 100 ml of solution. /4/ Equilibrates with the lactone. /5/ There is some claim that bacterial action on calcium α-gluconate produces L-guluronic acid. This fact is yet to be firmly established since no definitive derivative of L-guluronic acid has been produced. L-Guluronic forms the same phenylosazone as 5-deoxy-5-"keto"-α-gluconic acid. /6/ Passes through a minimum point in mutarotating.

Part VI. NATURAL PHOSPHATE ESTERS[1,2]

	Substance	Hydrolysis Constant k^3 1st Ester[4] Group	Temp °C	Medium	[α] Degrees[5]	Wave Length[6]	Compound	Conc.
1	Dihydroxyacetone phosphate	33.7	100	N HCl				
2	D-Fructose 1-phosphate	70	100	N HCl	-64.2	5461	Free acid	11.3
3					-39	5461	Ba salt	6.1
4					-52.1	5461	Brucine salt	
5	D-Fructose 6-phosphate	4.4	100	N HCl	+3.6	D	Ba salt	10
6	D-Fructose 1,6-diphosphate	52[6]	100	N HCl	+4.1	D	Free acid	13.6
7	α-D-Galactose 1-phosphate	5.9	37	0.25 N HCl	+108	D	K salt	2.6
8					+148	D	Free acid	1.7 (0.2 N HCl)
9					+92	D	Ba salt	2.3
10					+113	5461	Ba salt	
11	β-D-Galactose 1-phosphate	5.6	37	0.25 N HCl	+31.3	D	Trihydrate	1.2
12	D-Gluconic acid 6-phosphate	0.21	100	N HCl	+0.2	5461	Free acid	
13					+18	5461	Free acid lactone	
14	α-D-Glucose 1-phosphate	1.3	37	0.25 N HCl	+118	D	Free acid	1
15		5[7]	33	N HCl	+75.5	D	Ba salt	1.3
16					+78	D	K salt dihydrate	4
17					+90	5461	K salt dihydrate	4
18					+0.5[8]	D	Dibrucine salt octahydrate[9]	3
19	β-D-Glucose 1-phosphate	15[7]	33	N HCl	-20[10]	D	Dibrucine salt decahydrate[11]	1.7
20	D-Glucose 6-phosphate	0.23	100	N HCl	+35.7	D	Free acid	
21					+41.4	5461	Free acid	0.7
22					+18	D	Ba salt	
23					+21.2	5461	Ba salt	8.4
24					+21.2	D	K salt	1.3
25	α-D-Glucose 1,6-diphosphate	0.78	30	N H_2SO_4	+83 ± 4	D	Free acid	0.2
26	β-D-Glucose 1,6-diphosphate	3.15	30	N H_2SO_4	-19 ± 2	D	Free acid	0.4
27	D-Glyceraldehyde 3-phosphate[12]	37.5	100	N HCl	+12	D	Free acid	
28	D-Glyceric acid 2-phosphate				+24.3	D	Free acid	
29					-68	D	Free acid	(Molybdate ion)
30	D-Glyceric acid 3-phosphate	1.8[13]	125	N HCl	-14.5	D	Ba salt	
31					-725	D	Ba salt	(Molybdate ion)
32	D-Glyceric acid 1,3-diphosphate	26	38	Water	Very small	D		
33	D-Glyceric acid 2,3-diphosphate				-4 ± 0.5	D	Ba salt	15 (sq. HNO_3)
34					-4	D	Na salt	28
35	D-Glyceric acid 2,3-diphosphate (concluded)				-2 ± 0.3	D	Ba salt	6-17, (H_2O or 1 $NHNO_3$)
36					-5[12]	D	Na salt	6-14
37					+4.6±0.4[14]	D	Na salt	
38	α-L-Glycerophosphate (L-glycerol 1-phosphate)(L-glycerin 1-phosphate)	0.15	80	Water, pH 6.3	+1.0	D	Ag salt	6.5
39					-4.7	D	Dimethyl ether, dimethyl ester	
40					-5.3	D	Diethyl ether, diethyl ester	
41					-2.8 ± 0.1	D	Glycerl-phosphorylcholine	
42	D-Mannose 6-phosphate	0.29	100	N HCl	+15.1	5461	Free acid	1.7
43					+3.5	5461	Ba salt	0.7
44	β-D-Ribose 1-phosphate	1200	25	0.5 N HCl	-12.9	D	Free acid	
45	α-D-Ribose 3-phosphate	4.5	100	0.25 N HCl	-9.7	D	Na salt	3.8
46	D-Ribose 5-phosphate	0.5	100	0.25 N HCl	+6.0	D	Ba salt	3.7
47					+16.5	D	Free acid	3 (1 N HCl)
48					+20	D	Free acid	(0.2 N HCl)
49	β-D-Ribose[15], 2-deoxy-, 1-phosphate	13-17[13]		Acetate buffer pH 4.5				
50	β-D-Ribose, 2-deoxy-, 5-phosphate	50[13]	100	N HCl				
51	D-Ribulose 5-phosphate				-40	D	Free acid	
52	L-Sorbose 1-phosphate	60[13]	100	N HCl	-16.5	D	Mono K salt	2
53					-7.2	D	Ba salt dihydrate	2.5 (0.1 N HCl)
54	Trehalose monophosphate				+185	5461	Free acid	2.4
55					+132	5461	Ba salt	3.2
56					+31	5461	Brucine salt monohydrate	0.8
57	Unidentified keto-heptose monophosphate	4	100	N HCl	+8	5461	Ba salt	
58	D-Xylose 5-phosphate	4	100	N HCl	+3.2	D	Na salt	5
59					+5	D	Ba salt	2
60	D-Xylulose phosphate (D-xylokotose 1-phosphate)	86	100	N HCl				

/1/ In preparing this table the literature has been covered through 1952, and Chem. Abs. coverage has extended through Sept., 1953. /2/ Unless otherwise noted all data are for crystalline material. Phosphate esters known only from strictly chemical syntheses are excluded. Included are some compounds which have not actually been isolated as such, but for which evidence for probable existence or structure is at hand. /3/ Values are k x 10^3. /4/ The last ester group is that one that lies farthest in the sugar carbon chain structure from the primary hydroxyl carbon (or asymmetric center) which determines the parent sugar's α or β configuration. /5/ Taken at 20-25°C in water unless otherwise noted. /6/ D represents the sodium D line, 5896. /7/ Constants were determined on the dibrucine salts. /8/ Rotation taken at 21°C. /9/ Brucine salt melts at 173-178°C. /10/ Rotation taken at 29°C. /11/ Brucine salt melts at 160-165°C. /12/ The compound fuses above 75°C. Fischer, H. O. L., and Baer, E., Ber. 65:337, 1040, 1932. /13/ Calculated by the contributors of this table from the data of the original investigator, using k = 0.30/time in min for 50% hydrolysis. /14/ The signs of these rotations are actually opposite, as taken from the original journal articles. /15/ Deoxy-β-D-ribose 1-phosphate cyclobexylamine salt sinters and decomposes at 152°C.

	Glycoside	Formula	M.P.[1] °C	Rotation $[\alpha]_D$	Solubility[1] H_2O	Alc.	Eth., etc. (g/100 ml)	Occurrence	Uses	Aglycone	M.P.[1] °C	Rotation $[\alpha]_D$	Sugar
1	Absinthin	$C_{30}H_{40}O_8$	68		sl. s.	s.	s. eth., chl., bz., NaOH	Wormwood	Anemia; anorexia; schlorhydria; constipation.				Glucose
2	Aesculin	$C_{15}H_{16}O_9$	205 d. [2]	-38	0, 175	s	sl. s, eth., s. h., chl., NaOH	Horse chestnut tree[3,4]	Instead of quinine in intermittent fever; neuralgia; lupus vulgaris.	Aesculetin	270 d.		Glucose
3	Aloin	Mixture			s.	s.	sl. s. eth., chl.	Aloe spp	Chronic constipation; amenorrhea.				Pentoses
4	Amygdalin	$C_{20}H_{27}O_{11}N$	220[2]	-42	8.3 h.	sl. s.	i. eth.	Almonds	Expectorant.	a-Mandelonitrile			Glucose
5	Apiin	$C_{26}H_{42}O_{16}$	228[2]		s. h.	sl. s. h.	i. eth.	Celery; parsley	Diuretic; insecticide; dropsy.	Apigenin	350		Glucose; apiose
6	Arbutin	$C_{12}H_{16}O_7$	195-200	-64	12, 5	7, 7	i. eth., CS_2, chl.	Cranberry, pear tree[3]	Diuretic.	Hydroquinone	170		Glucose
7	Barbaloin	$C_{20}H_{18}O_8$	148		s.	s.	sl. s. eth.	Aloe spp	Chronic constipation.	Aloe-emodin	224		Glucose
8	Bryonin	$C_{48}H_{66}O_{18}$	208		sl. s.	s.	i. eth., chl.	Bryonia alba	Dropsy; congested liver; pericarditis; rheumatism.[5]	Bryogenin			Glucose
9	Carminic acid	$C_{22}H_{20}O_{13}$	136 d.		s.	s.	s. eth., NaOH; i. chl.	Cochineal	Indicator. Pigment in color photography, paints, bacteriology.	Carmine red			
10	Coniferin	$C_{16}H_{22}O_8$	185	-68	0, 5	sl. s.	i. eth.	Conifers; sugar beet	Preparation of vanilla.	Coniferyl alcohol	73-74		Glucose
11	Convallatoxin	$C_{29}H_{42}O_{10}$	247	0	0, 05	s.	sl. s. eth., chl.	Lily of the valley	Cardiac glycoside.	Strophanthidin	235	+43, 1	Rhamnose
12	Convolvulin	$C_{54}H_{96}O_{27}$	155-168		sl. s.	s.	i. eth.; s. acet.	Jalap resin, Canadian hemp	Purgative. Cardiotonic.	Methylethylacetic acid; tiglic acid			Glucose; rhodeose
13	Crocin	$C_{44}H_{64}O_{24}$	186 d. [2]		sl. s.	sl. s.	i. eth., chl.	Saffron, crocus, gardenia	Plays role in sex process of algae.	Crocetin	285		Gentiobiose
14	Cymarin	$C_{30}H_{44}O_9$	139	+35	s.		s. chl., me. al.,		Cardiac stimulant; tonic.	Strophanthidin	235	+43, 1	Cymarose
15	Daphnin	$C_{15}H_{16}O_9$	125 d. [2]	-115	sl. s.	s.	i. eth.; s. NaOH	Daphne	Inflammation and vesication of skin; epispastic.	7, 8-Dihydroxycoumarin	253 d.		Glucose
16	Diginin	$C_{28}H_{40}O_7$	155-183	-176	i.		sl. s. eth.; s. chl., CCl_4	Digitalis purpurea[3]	Digitalis glycoside. Cardiotonic.	Digitogenin	115	-226	Giginose
17	Digitonin	$C_{55}H_{90}O_{29}$	235 d. [2]	-54	s.	1. 8 abs.	i. eth., chl.	Digitalis purpurea[6]	Test for cholesterol and some other sterols.	Digitogenin	250	-81	Glucose; galactose
18	Digitoxin	$C_{41}H_{64}O_{13}$	256	+4. 8	0, 001	1. 7	i. eth.	Digitalis purpurea	Congestive heart failure. Cardiotonic.	Digitoxigenin + digitoxe	253	+19, 1	Digitoxe
19	Digoxin	$C_{41}H_{64}O_{14}$	265 d.	+13, 3	0, 001	0, 45	i. eth., chl.,	Digitalis lanata	Digitalis glycoside. Cardiotonic.	Digoxigenin + digitoxose	222	+27	
20	Gaultherin	$C_{19}H_{26}O_{12}$	179-180	-58	s.	s.	i. eth.; s. acet.	Wintergreen plant	Source of methyl salicylate.	Methyl salicylate	-8, 6	+1. 2	Glucose; xylose
21	Gitonin	$C_{50}H_{82}O_{23}$	272	-51	sl. s.	0. 98	i. eth.; s. acet.	Digitalis purpurea	Similar to digitonin.	Gitogenin	272	-61	Galactose; xylose
22	Gitoxin	$C_{41}H_{64}O_{14}$	285	+3. 5	sl. s.		s. eth.; i. chl., acet.	Digitalis lanata	Minor digitalis glycoside.	Gitoxigenin	235	+38. 5	Digitoxose
23	Gratiolin	$C_{43}H_{70}O_{15}$	235-237		sl. s.	s.	sl. s. eth.; s. chl.	Gratiola glucoside	Cathartic; emetic diuretic; dropsy.	Gratiogenin	198		Glucose
24	Hesperidin	$C_{28}H_{34}O_{15}$	260-262	-76	v. sl. s.	sl. s. me. al.	i. eth., chl.; s. NaOH	Citrus plants	Purpura; vascular complications; hypertension; anti-hyaluronidase.	3', 5, 7-Trihydroxy-flavanone	390 d.		Glucose
25	Indican	$C_{14}H_{17}O_6N$	176-178	-66	s.	s.	sl. s. eth., chl.	Indigofera spp		Indoxyl	390		Glucose
26	Iridin	$C_{24}H_{26}O_{13}$	N208		v. sl. s.	s. h.	i. eth., chl.	Rhizome of iris	Jaundice; constipation; amenorrhea.	Irigenin	186		Glucose
27	Jalapin	$C_{34}H_{56}O_{16}$	131-150		sl. s.	s.	s. eth., chl.	Scammony resin	Chronic constipation.	Jalapinolic	67-69		Various
28	Khellinin	$C_{19}H_{20}O_{10}$	175[2]	0	sl. s.	s. me. al.	i. eth.	Toothpick ammi[6]	Angina pectoris; coronary thrombosis; bronchial asthma.	2-Hydroxymethyl-5-methoxy-furanochrome	155		Glucose
29	Ouabain	$C_{29}H_{44}O_{12}$	185 d.	-32, 5	1, 2	1	sl. s. eth., chl.	Strophanthus gratus[6]	As for digitalis.	Ouabagenin	255	+11, 3	Rhamnose
30	Phlorisin	$C_{21}H_{24}O_{10}$	110[2]	-52	0, 1	25	i. eth., chl.	Fruit trees[4]	Additive to lubricating oils.	Phloretin	271		Glucose
31	Picrocrocin	$C_{16}H_{26}O_7$	154-156	-50	s.	s.	sl. s. eth., chl.	Crocus	Coloring; flavoring.	Safranol			Glucose
32	Quercitrin	$C_{21}H_{20}O_{11}$	182-185		i. c.	s.	i. eth.; s. NaOH	Astringent; tonic; textile dye.	Quercetin[4]	Quercetin	314 d.		Glucose; rhamnose
33	Rutin	$C_{27}H_{30}O_{16}$	215 d.		sl. s. c.	sl. s.	i. eth., chl.	Buckwheat plant	Vascular purpura; hypertension; diabetes; inc., capillary fragility.	Quercetin	313-4		Glucose; rhamnose
34	Salicin	$C_{13}H_{18}O_7$	199-201	-67	4	1	i. eth., chl.	Poplar, willow[4]	Analgesic, Rheumatism; malaria; typhoid; chorea.	Saligenin	87		Glucose
35	Sarsasaponin	$C_{45}H_{74}O_{17}$	240	-66	s.	s. h.	sl. s. eth.		Production of progesterone, testosterone	Sarsasapogenin	200	-75	Glucose; rhamnose
36	Solanine	$C_{45}H_{73}O_{15}N$	285 d.	-60	s.	s. h.	i. eth., chl.	Solanum	Vomiting of pregnancy; asthma; epilepsy; locomotor ataxis; tetanus.	Solanidine	219	-29	Glucose; galactose; rhamnose
37	Streptomycin $\cdot$ HCl	$C_{21}H_{39}O_{12}N_7 \cdot 3HCl$		-84	s.	v. sl. s.	i. eth., chl.	Cultures of Streptomyces griseus	Tuberculosis; susceptible gram-negative bacteria.	Streptidine			a.-Streptose
38	Tannic acid	$C_{76}H_{52}O_{46}$	210-5 d.		v. s.	sl. s.	v. sl. s. eth., chl.	Oak, sumac[6]	Tanning; mordant in dyeing and printing.	Gallic acid	235 d.		Glucose

/1/ Abbreviations: aba. = absolute; acet. = acetone; bz. = benzene; c. = cold; chl. = chloroform; d. = decomposes; eth. = ether; h. = hot; i. = insoluble; me. al.= methyl alcohol; s. = soluble; sl. = slightly; v. = very. /2/ Hydrated salt. /3/ Leaves. /4/ Bark. /5/ It has been reported that this compound is therapeutically inactive. /6/ Seeds.

	Common Name	Systematic Name	Formula	Molecular Weight	M. P. or Fr. p.[1] °C	Boiling Point[2] °C	Specific Gravity[3]	Refractive Index[4] n x D	Neutralization Value[5]	Iodine Value (Calculated)[6]	Solubility[7]	Source
						Saturated Fatty Acids						
1	Formic	Methanoic	HCOOH	46, 0	8.6	100.8	1.220^{20}	1.3714^{20}	1219		s, w.	Red ant
2	Acetic	Ethanoic	CH_3COOH	60, 1	16, 7	118.2	1.049^{20}	1.3716^{20}	934.2		s, w.	Vinegar
3	Propionic	Propanoic	C_2H_5COOH	74, 1	-22.0	141.1_{1}	0.992^{20}	1.3874^{20}	757.3		s, w., al., eth., chl.	
4	Butyric	Butanoic	C_3H_7COOH	88, 1	-7, 9	162.7^{69}	0.958^{20}	1.3390^{20}	636.8		s. w., eth., al.	Butter fat
5	Valeric	Pentanoic	C_4H_9COOH	102, 1	-34.5	187			549.3		sl. s. w., s., al., eth.	
6	Caproic	Hexanoic	$C_5H_{11}COOH$	116, 2	-3, 9	205, 3	0.9313^{15}	1.4163^{20}	483.0		sl. s. w., s. eth., al.	Butter fat, palm oil
7	Enanthic	Heptanoic	$C_6H_{13}COOH$	130, 2	-8, 9	223, 5	0.9221^{15}	1.4130^{20}	431.0		v. sl. s. w., s., al., eth.	Violet leaf oil
8	Caprylic	Octanoic	$C_7H_{15}COOH$	144, 2	16, 5*	239, 3	0.9088^{400}	1.4285^{20}	389.1		v. sl. s. w., s. eth., al., bz	Butter fat, coconut oil
9	Pelargonic	Nonanoic	$C_8H_{17}COOH$	158. 2	12, 2*	254			354, 6		v. sl. s. w., s., al., eth., chl.	
10	Capric	Decanoic	$C_9H_{19}COOH$	172, 3	31, 3*	268, 7	0.8858^{40}	1.4285^{40}	325, 7		sl. s. w., s., eth., al.	Butter fat, coconut oil
11	Undecylic	Undecanoic	$C_{10}H_{21}COOH$	186, 3	28, 3*	295			301.2		s., al., eth., chl.	
12	Lauric	Dodecanoic	$C_{11}H_{23}COOH$	200, 3	43. 9*	225^{100}	0.8690^{50}	1.426^{100}	280, 1		sl. s. h. w. ; s, acet., al., eth.	Laurel kernel oil
13	Tridecylic	Tridecanoic	$C_{12}H_{25}COOH$	214, 3	41. 8*	236^{100}			261.8		s. al., eth.	
14	Myristic	Tetradecanoic	$C_{13}H_{27}COOH$	228, 4	54, 1*	250.5^{100}	0.8622^{54}	1.4275^{70}	245.7		s. al., eth., acet, chl., glac. acet, a.	Nutmeg, butter fat
15	Palmitic	Hexadecanoic	$C_{15}H_{31}COOH$	256, 4	62. 7*	268^{100}	0.852^{62}	1.4339^{60}	218.8		s. h. al., eth.	Palm oil
16	Stearic	Octadecanoic	$C_{17}H_{35}COOH$	284, 5	69, 6*	291^{100}	0.9408^{20}	1.4332^{70}	197.2		s. al., eth., acet., bz., CS_2.	Mutton tallow, cocoa butter
17	Arachidic	Eicosanoic	$C_{19}H_{39}COOH$	312, 5	75, 4	$203-205^{1}$	0.8240^{100}	1.4250^{100}	179.5		s. chl., eth.	Peanut oil
18	Behenic	Docosanoic	$C_{21}H_{43}COOH$	340, 6	80, 0	306^{60}	0.8221^{100}	1.4270^{100}	164.7		sl. s. eth., al.	Peanut oil, behen oil
19	Lignoceric	Tetracosanoic	$C_{23}H_{47}COOH$	368, 6	84, 2		1.4287^{100}		152.2		sl. s. al., s. acet., bz., eth.	Beech-tar paraffin
20	Cerotic	Hexacosanoic	$C_{25}H_{51}COOH$	396, 7	87, 7		0.8198^{100}	1.4301^{100}	141.4		s. h. me. al., h. al., h. bz., h. chl., h. acet.	Beeswax, wool wax
21	Montanic	Octacosanoic	$C_{27}H_{55}COOH$	424, 7	90, 9		0.8191^{100}	1.4313^{100}	132, 1		s. pet. eth., h. al., glac. acet. a.	Beeswax, montan wax
22	Melissic	Triacontanoic	$C_{29}H_{59}COOH$	452, 9	93, 6			1.4325^{100}	123.9		s. h. al., chl., CS_2.	Beeswax, mineral waxes
23	Lacceroic	Dotriacontanoic	$C_{31}H_{63}COOH$	480, 8	96, 2				116, 7		s. bz., acet., a., chl.	Stick-lac wax
24	Geddic	Tetratriacontanoic	$C_{33}H_{67}COOH$	508, 9	98. 3-0. 5				110.2		s. bz., acet., chl.	Ghedda wax
25		Hexatriacontanoic	$C_{35}H_{71}COOH$	536, 9	99, 9				104.5			
						Unsaturated Fatty Acids (Monoethenoid)						
26		2-Hexenoic	$C_6H_{10}O_2$	114. 1	32		0.9540^{-}	1.4466^{40}	491.5	222, 5		Japanese peppermint oil
27	Obtusilic	4-Decenoic	$C_{10}H_{18}O_2$	170, 2		$148-150^{13}$	0.9197^{20}	1.4497^{20}	329.6	149, 1	s. eth., bz.	Tobaku oil
28	Caproleic	9-Decenoic	$C_{10}H_{18}O_2$	170. 2		$143-8^{15}$	0.9238^{15}	1.4507^{15}	329.6	149, 1	s. al., eth.	Butter fat, whale oil
29	Linderic	4-Dodecenoic	$C_{12}H_{22}O_2$	198. 3	1. 0-1. 3	$170-172^{13}$	0.9081^{20}	1.4520^{20}	282, 9	128.0	s. eth., chl., bz., pet. eth.	Tobaku oil
30	Lauroleic	5-Dodecenoic	$C_{12}H_{22}O_2$	198, 3			0.9130^{15}	1.4535^{15}	282, 9	128.0	s. eth., chl., bz., pet. eth.	Herring oil, whale oil
31		9-Dodecenoic	$C_{12}H_{22}O_2$	198, 3					282, 9	128.0	s. eth., chl., bz., pet. eth.	Butter fat, cochineal wax
32	Tsuzuic	4-Tetradecenoic	$C_{14}H_{26}O_2$	226, 4	18. 0-0. 5	$185-188^{13}$	0.9055^{15}	1.4575^{15}	247, 9	112, 2	s. eth., bz.	Tsuzu seeds
33		5-Tetradecenoic	$C_{14}H_{26}O_2$	226, 4			0.9046^{20}	1.4552^{20}	247, 9	112, 2	s. eth., bz.	Whale oil
34	Myristoleic	9-Tetradecenoic	$C_{14}H_{26}O_2$	226, 4			0.9018^{20}	1.4549^{20}	247.9	112, 1	s. eth., bz.	Butter fat, whale oil
35	Palmitoleic	9-Hexadecenoic	$C_{16}H_{30}O_2$	254, 4	-1				220, 5	99, 8	s. eth., bz.	Marine oils, milk fat
36	Petroselenic	6-Octadecenoic	$C_{18}H_{34}O_2$	282, 5	32-33	$237-238^{18}$	0.8824^{35}	1.4533^{47}	198.6	89, 9	s. al., eth.	Parsley seed oil
37	Oleic	9-Octadecenoic	$C_{18}H_{34}O_2$	282, 5	13	$200-201^{1.2}$	0.895^{20}	1.4582^{20}	198.6	89, 9	s. acet., me. al., eth.	Olive oil, pork fat
38	Vaccenic	11-Octadecenoic	$C_{18}H_{34}O_2$	282, 5	6-10				198.6	89, 9	s. acet., me. al., eth.	Butter fat, mutton fat
39	Gadoleic	9-Eicosenoic	$C_{20}H_{38}O_2$	310, 5					180, 7	81, 8	s. acet., me. al.	Sperm oil, cod-liver oil
40		11-Eicosenoic	$C_{20}H_{38}O_2$	310, 5	50	267^{15}			180, 7	81, 8	s. al.	Jajoba oil
41	Cetoleic	11-Docosenoic	$C_{22}H_{42}O_2$	338, 6					165, 7	75	s. al.	Marine oils
42	Erucic	13-Docosenoic	$C_{22}H_{42}O_2$	338, 6	33, 5	$241-243^{5}$			165, 7	75.0	v. s. al., eth.	Mustard seed oil
43	Selacholeic	15-Tetracosenoic	$C_{24}H_{46}O_2$	366, 6	42, 5-43				153.0	69.2	s. al., eth., acet.	Shark liver oil
44	Ximenic	17-Hexacosenoic	$C_{26}H_{50}O_2$	394, 7					142, 2	64, 3	s. eth., chl., bz., pet. eth.	Tallow wood
45	Lumequeic	21-Triacontenoic	$C_{30}H_{58}O_2$	450, 8					124, 5	56, 3	s. eth., chl., bz., pet. eth.	Tallow wood
						Unsaturated Fatty Acids (Polyethenoid)						
46	Linoleic	9, 12-Octadecadienoic	$C_{18}H_{32}O_2$	280, 4	-5, 0 to -5, 2	$20, 2^{1.4}$	0.9038^{18}	$1.4718^{1.5}$	200. 1	181, 0	s. acet., me. al., eth.	Soybean oil, linseed oil
47	Hiragonic	6, 10, 14-Hexadecatrienoic	$C_{16}H_{26}O_2$	250, 4			0.9324^{15}	1.4876^{15}	224, 1	304. 2	s. acet., al., eth., pet. eth.	Sardine oil
48	Linolenic	9, 12, 15-Octadecatrienoic	$C_{18}H_{30}O_2$	278, 4	-14. 4 to -14. 5	$157-158^{0.001}$	0.9046^{20}	1.4780^{20}	201, 5	273, 5	s. acet., al., eth., pet. eth.	Linseed oil, hempseed oil
49	Eleostearic	9, 11, 13-Octadecatrienoic	$C_{18}H_{30}O_2$	278, 4	48	235^{12}		1.5112^{50}	201, 5	273, 5	v. s. eth., s. al., CS_2	Tung oil, esang seed oil
50	Moroctic	4, 8, 12, 15-Octadecatetraenoic	$C_{18}H_{28}O_2$	276, 4			0.9334^{15}	1.4930^{15}	203, 0	372, 6	s. acet., al., eth., pet. eth.	Sardine oil
51	Parinaric	9, 11, 13, 15-Octadecatetraenoic	$C_{18}H_{28}O_2$	276. 4	85-6				203, 0	367, 3	s, pet. eth., eth.	"Akaritton" seed fat

							Unsaturated Fatty Acids (Polyethenoid) (Concluded)						
52	Arachidonic	5,8,11,14-Eicosa-tetraenoic	$C_{20}H_{32}O_2$	304.5	-49.5			1.4824[20]	184.3	333.5	s. acet., me. al.	Glandular organs, liver lipids	
53	Timnodonic	4,8,12,15,18-Eicosa-pentaenoic	$C_{20}H_{30}O_2$	302.4					185.5	419.7	s. eth., chl., bz., pet. eth.	Sardine oil	
54	Clupanodonic	4,8,12,15,19-Docosa-pentaenoic	$C_{22}H_{34}O_2$	330.5	-78			0.9385[15] 1.5039[15]	169.8	384.0	s. acet., eth.	Herring oil, cod-liver oil	
55	Nisinic	4,8,12,15,18,21-Tetracosahexzenoic	$C_{24}H_{36}O_2$	356.5					157.4	427.2	s. eth., chl., bz., pet. eth.	Sardine oil, cod-liver oil	
							Hydroxy- and Keto-fatty Acids						
56	Sabinic	12-Hydroxy-dodecanoic	$C_{12}H_{24}O_3$	216.2	84				259.5		s. al., h. bz.	Juniper wax	
57	Ipurolic	3, 11-Dihydroxy-tetradecanoic	$C_{14}H_{28}O_4$	260.2	100-101				215.6		s. eth., chl.	Japanese morning glory seed	
58	Convolvulinolic	11-Hydroxy-pentadecanoic	$C_{15}H_{30}O_3$	258.2	63.5-64				217.3		s. eth., pet. eth., chl., al.	Convolvulin resin	
59	Jalapinolic	11-Hydroxy-hexadecanoic	$C_{16}H_{32}O_3$	272.3	68-69				206.0		s. eth., al., pet. eth.	Jalap-root wax	
60	Juniperic	16-Hydroxy-hexadecanoic	$C_{16}H_{32}O_3$	272.3	95				206.0		s. bz., eth., al.	Conifer waxes	
61	Dihydroxystearic	9, 10-Dihydroxy-octadecanoic	$C_{18}H_{36}O_4$	316.5	cis 95 trans 132				177.3		s. eth., h. w., al. (cis); pet. eth., h. al (trans).	Castor oil	
62	Phellonic	2-Hydroxy-docosanoic	$C_{22}H_{44}O_3$	356.6	88-91				157.3		s. chl., eth., acet., pyr., glac. acet. a.	Cork, subein, brain lipids	
63	Cerebronic	2-Hydroxy-tetracosanoic	$C_{24}H_{48}O_3$	384.6	99.5 - 100.5				145.9		s. eth., pyr., acet., h. al.	Brain lipids	
64	Hydroxycerotic	2-Hydroxy-hexacosanoic	$C_{26}H_{52}O_3$	412.7	86.5				135.9		s. eth., acet., pyr., glac. acet. a.	Brain lipids	
65	Lactarinic	6-Keto-octa-decanoic	$C_{18}H_{34}O_3$	298.4	86				188.0		s. h. al., eth., chl.	Lactarius mushrooms	
66	Ricinoleic	12-Hydroxy-9-octadecenoic	$C_{18}H_{34}O_3$	298.4	5.5			0.940[27.4] 1.4716[20]	188.0	170.1	s. acet., pet. eth.	Castor oil	
67	Hydroxynervonic	2-Hydroxy-9-tetracosenoic	$C_{24}H_{46}O_3$	382.6					146.6	66.3	s. eth., chl., bz.	Brain lipids	
							Branched Chain and Cyclic Fatty Acids						
68	Isobutyric	2-Methyl propanoic	$C_4H_8O_2$	88.1	-46	155	0.9529[15]	1.3964[15]	636.8		s. al., pet. eth.		
69	Isovaleric	3-Methyl butanoic	$C_5H_{10}O_2$	102.1	-51	176.7	0.937[15]	1.4017[22.4]	549.34		s. w., al., chl., eth.	Dolphin oil	
70	Isopalmitic	14-Methyl penta-decanoic	$C_{16}H_{32}O_2$	256.4	62.4				218.79		s. acet., pet. eth.		
71	Isostearic	16-Methyl hepta-decanoic	$C_{18}H_{36}O_2$	284.5	69.5				197.22		s. acet., pet. eth.		
72	Tuberculostearic	10-Methyl octa-decanoic	$C_{19}H_{38}O_2$	298.5	10-11		0.8771[25]	1.4512[25]	187.95		s. eth., al., acet.	Wax of tubercle bacilli	
73	Phytomonic		$C_{20}H_{40}O_2$	312.5	24				179.5		s. eth., al.	Crown gall bacilli	
74	Phthioic		$C_{26}H_{52}O_2$	396.7	20-21		0.8763[25]	1.4628[25]	141.5		s. acet., eth.	Tubercle bacilli	
75	Mycocerosic		$C_{30}H_{60}O_2$	452.	27-28			1.4532[40]	124.1		s. eth., chl.	Tubercle wax	
76	Mycolic		$C_{88}H_{172}O_4$	1294.2	54-56				43.35		s. eth.	Human tubercle bacilli	
77	Hydnocarpic	11-(2-Cyclopen-tenyl)-undecanoic	$C_{16}H_{28}O_2$	252.4	59-60				222.3	100.6	s. pet. eth., al., chl.	Chaulmoogra oil	
78	Chaulmoogric	13-(2-Cyclopen-tenyl)-tridecanoic	$C_{18}H_{32}O_2$	280.4	68.0-.5	247-248[20]			200.1	90.5	s. acet., chl., eth.	Chaulmoogra oil	
79	Gorlic	13-(2-Cyclopentenyl)-6-tridecanoic	$C_{18}H_{30}O_2$	278.4	6(liq)	232.5	0.9436[25]	1.4782[25]	201.5	182.5	s. acet.	Chaulmoogra oil	
80	Tariric	6-Octadecynoic	$C_{18}H_{32}O_2$	280.4	liquid				200.06	181.0	s. h. al.		

/1/ *=freezing point. /2/ At atmospheric pressure (760 mm of mercury) unless otherwise indicated by specific pressure in superscript. /3/ At temperature indicated in superscript referred to water at 4° C. /4/ Refractive index (n) is given for the sodium D-line at temperature shown in superscript. /5/ mg KOH required to neutralize one g of acid. /6/ Grams of iodine absorbed by 100 g of acid. /7/ a. = acid; acet. = acetone; acet. a. = acetic acid; al. = alcohol; bz. = benzene; chl. = chloroform; eth. = ether; glac. = glacial; h. = hot; me. = methyl; pet. = petroleum; pyr. = pyridine; s. = soluble; sl. = slightly; v. = very; w. = water.

Values are considered typical rather than average, and frequently represent specific analyses for particular samples (especially in the case of the constituent fatty acids). Extreme variations may occur, depending on a number of variables, such as source, treatment, and age of a fat or oil.

Fat or Oil	Constants					Constituent Fatty Acids, g/100 g total fatty acids													
						Saturated								Unsaturated					
	Melting or "Solidification Point °C	Specific Gravity or "Density $15^{0}/15^{0}C$	Refractive Index $n\ \frac{40^{0}C}{d}$	Iodine Value	Saponification Value	Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Arachidic	Palmitoleic	Oleic	Linoleic	Linolenic	C20 Eicosenoic	C21 Polyethenoic	Others
Vegetable Fats and Oils																			
1 Babassu oil (Attalea funifera)	22-26	$^{a}0.893^{60}$	1.4416^{0}	15.5	247	0.2	4.8	6.6	44.1	15.4	8.5	2.7	0.2		16.1	1.4				
2 Castor oil (Ricinus communis)	*-18.0	0.961	1.4770	85.5	180.3	←					2.4	→			7.4	3.1				
3 Cocoa butter (Theobroma cacao)	34.1	0.964	1.4568	36.5	193.8						24.4	35.4			38.1	2.1				
4 Coconut oil (Cocos nucifera)	25.1	0.924	1.4493	10.4	268	0.8	5.4	8.4	45.4	18.0	10.5	2.3	0.4^{4}	0.4	7.5	Trace				
5 Corn oil (Zea maye)	*-20.0	0.922	1.4734	122.6	192.0					1.4	10.2	3.0		1.5	49.6	34.3				
6 Cottonseed oil (Gossypium hirsutum)	*-1.0	$0.917^{25/25}$	1.4735	105.7	194.3					1.4	23.4	1.1	1.3	2.0	22.9	47.8				
7 Linseed oil (Linum usitatissimum)	*-24.0	0.938	1.4782^{25}	178.7	190.3						6.3	2.5	0.5		19.0	24.1	47.4			$+^{5}$
8 Mustard oil (Brassica alba)		0.9145^{6}	1.4756^{0}	102^{6}	174^{6}					1.37					27.27	16.67^{1}	1.87			$+^{8}$
9 Neem oil (Azadirachta indica)	-3	0.917^{6}	1.4615^{6}	71^{6}	194.5^{6}					2.6^{1}	14.1^{7}	24.0^{7}	0.8^{7}		58.5[7]					
10 Nigerseed oil (Guizotia abyssinica)		0.926^{6}	1.4716^{0}	128.5^{6}	190^{6}					3.3^{1}	8.2^{7}	4.8^{7}	0.5^{7}		30.3[7]	57.3^{7}				
11 Oiticica oil (Licania rigida)		$0.976^{25/25}$		140-180							11.3^{9}	→			6.2					$+^{10}$
12 Olive oil (Olea Europaea sativa)	*-6.0	0.918	1.4679	81.1	189.7					Trace	6.9	2.3	0.1		84.4	4.6				
13 Palm oil (Elaeis guineeis)	35.0	0.915	1.4578	54.2	199.1					1.4	40.1	5.5			42.7	10.3				
14 Palm kernel (E.guineesis)	24.1	0.923	1.4569	37.0	219.9		2.7	7.0	46.9	14.1	8.8	1.3			18.5	0.7				$+^{11}$
15 Peanut oil (Arachis hypogaea)	*3.0	0.914	1.4691	93.4	192.1						8.3	3.1	2.4		56.0	26.0				
16 Perilla oil (Perilla ocimicoides)		$^{a}0.935^{15}$	1.4812^{25}	195	192						9.6^{9}	→			17.8		17.5			
17 Poppyseed oil (Papaver aomniferum)	*-15	0.925^{5}	1.4685^{5}	135^{5}	194^{5}						4.8^{7}	2.9^{7}			30.17	62.27				
18 Rapeseed oil (Brassica campestris)	*-10	0.915	1.4706	98.6	174.7						1				32	15	1			$+^{12}$
19 Safflowerseed oil (Carthamus tinctorius)		$^{a}0.900^{60}$	1.4626^{0}	145	192						6.8^{9}	→			18.6	70.1	3.4			
20 Sesame oil (Sesamum indicum)	*-6.0	$0.919^{25/25}$	1.4646	106.6	187.9						9.1	4.3	0.8		45.4	40.4				
21 Soybean oil (Soja hispida)	*-16.0	0.927	1.4729	130.0	190.6					0.2	0.1	9.8	2.4	0.9	0.4	28.9	50.7	6.5		
22 Sunflowerseed oil (Helianthus annuus)	*-17.0	0.923	1.4694	125.5	188.7							5.6	2.2	0.9		25.1	66.2			
23 Tung oil (Aleurites fordii)	*-2.5	0.934	1.5174^{25}	168.2	193.1	←							4.6^{9}	→		4.1	9.6			$+^{14}$
24 Wheat germ oil (Triticum vulgare)				125		←							16.0^{9}	→		28.1	52.3	3.6		
Land-animal Fats and Oils																				
25 Butter fat	32.2	$0.911^{40/15}$	1.4548	36.1	227	2.0	0.5	2.3	2.5	11.1	29.0	9.2	2.4	4.6	26.7	3.6				$+^{15}$
26 Human depot fat	*15	0.918	1.4602	67.6	196					2.7	24.0	8.4		5	46.7	10.2				$+^{16}$
27 Lard oil	*30.5	0.919	1.4615	58.6	194.6					1.3	28.3	11.9		2.7	47.5	6				$+^{17}$
28 Neatsfoot oil		$0.916^{25/25}$	1.464^{25}	69-76	190-199						17-18	2-3			74-76					
29 Tallow, beef				49.5	197					6.3	27.4	14.1			49.6	2.5				
30 Tallow, mutton	*42.0	0.945	1.4565	40	194					4.6	24.6	30.5			36.0	4.3				
Marine-animal Fats and Oils																				
31 Cod liver oil (Gadus morrhua)		0.925^{25}	1.4812^{25}	165	186					5.8	8.4	0.6		20.0	29.7^{18}			25.4	9.6	
32 Herring oil (Clupea harengus)		0.900^{60}	1.4610^{60}	140	192					7.3	13.0	Trace		4.9			20.7	30.1	23.2	
33 Menhaden oil (Brevoortia tyrannus)		0.903^{60}	1.4644^{60}	170	191					5.9	16.3	0.6	0.6	15.5			29.6	19.0	11.7	$+^{19}$
34 Sardine oil (Sardinops caerulea)		0.905^{60}	1.4660^{60}	185	191					5.1	14.6	3.2		11.8	17.8^{18}			18.1	14.0	$+^{20}$
35 Sperm oil, body (Physeter macrocephalus)				76-88	122-130				1	5	6.5			26.5	37	19			1	$+^{21}$
36 Sperm oil, head (P. macrocephalus)				70	140-144			3.5	16	14	8	2		15	17	6.5				$+^{22}$
37 Whale oil (Balaena mysticetus)		0.89^{260}	1.4606^{0}	120	195				0.2	9.3	15.6	2.8		14.4	35.2			13.6	5.9	$+^{23}$

/1/ Underlined superscripts indicate temperature at which density was determined, or, for specific gravity, the temperature of measurement referred to that of water at the indicated temperature; where no superscript appears, the sp. gr. is that calculated to 15°C referred to water at 15°C. /2/ Underlined superscripts indicate temperature of measurement, if other than 40°C. /3/ Contains 87% ricinoleic acid. /4/ Includes behenic and lignoceric acid. /5/ Behenic, 0.2. /6/ Calculated from reported range. /7/ % by weight. /8/ Behenic, 1.1; lignoceric, 1.0; erucic, 51.0. /9/ Includes behenic acid. /10/ Licanic, 82.5. /11/ Behenic, 3.1; lignoceric, 1.1. /12/ Erucic, 50. /13/ C_{14} monoethenoic, 0.1. /14/ Eleostearic, 90.7. /15/ Butyric, 3.6; decenoic, 0.1; C_{12} monoethenoic, 0.1; C_{14} monoethenoic, 0.9; gadoleic plus erucic, 1.4. /16/ Gadoleic plus erucic, 2.5. /17/ C_{14} monoethenoic, 0.2; gadoleic plus erucic, 2.1. /18/ Oleic plus linoleic. /19/ Behenic, 0.8. /20/ C_{14} monoethenoic, traca; C_{14} polyethenoic, 15.4. /21/ C_{12} monoethenoic, 4; gadoleic, 19. /22/ C_{12} monoethenoic, 4; C_{14} monoethenoic, 14; gadoleic, 6.5. /23/ C_{14} monoethenoic, 2.5; C_{24} polyethenoic, 0.2.

13. WAXES: PHYSICAL AND CHEMICAL CHARACTERISTICS

	Wax	Melting Point °C	Refractive Index n_D^{t1}	Specific Gravity or Density* 15°/15°C[2]	Iodine Value	Acid Value	Saponification Number
1	Alcocer	67-79	1.455-1.463[85]	0.982-0.986*[15]	14.4-20.4	12.7-18.1	35-86
2	Bamboo leaf	79-80		0.961[25]	7.8[3]	14.5	43.4
3	Bayberry (Myrtle)	41-53	1.436-1.446[80]	0.981-0.991*[15]	1.0-3.9	2.5-4.5	205-217
4	Beeswax, crude	62-67	1.439-1.453[80]	0.927-0.970	6.8-16.4[4]	16-25	85-100
5	Beeswax, white, U.S.P.	61-70	1.447-1.465[65]	0.959-0.975*[15.5]	7-11	17-24	85-109
6	Beeswax, yellow	62-65	1.442-1.449[65]	0.923-0.970	3.4-11	19-22	85-106
7	Candelilla	70-75	1.454-1.463[85]	0.945-0.996	5.2-32.8	15-25	46.7-59.7
8	Caranday	80-85		0.990[25]	8.0-8.9	5-9.5	64.5-78.5
9	Carnauba	82-85	1.467-1.472[40]	0.990-1.001	7.2-13	6-15	65-90
10	Castor oil, hydrogensted	83-88		0.980-0.990*[20]	2.5-8.5	1-5	83-88
11	Chinese insect	80.5-84	1.4566-1.4568[40]	0.932-0.970	1.4	0.2-1.5	70-93
12	Cotton	70-79		0.957-0.998[25]	11-24.5	21-32	109-180
13	Cranberry	194-218		0.970-1.010*[15]	44.2-57.4	42.1-69.3	85-134
14	Douglasfir	61-63		1.050[20]	27.8-62.5	58.6-80.1	160-210
15	Esparto	67.5-81		0.987-0.989	18-22	22.7-23.9	69.8-79.3
16	Fiber	61-80.5		0.968-0.988	11-23	10.6-34	61-79
17	Flax	65-75		0.908-0.985	25-35	12-25	65-85
18	Ghedda	60.4-66.4	1.440[80]	0.956-0.973	4.8-11.4[5]	3.5-10.5	86-130
19	Japan	48.5-54.5		0.975-0.993	4.5-12.8	6-20	206-237
20	Jojoba	11.2-11.8	1.465[25]	0.864-0.899	81.7-83.4[4]	0.23-0.57	99.2-95.0
21	Madagascar	88.0			3.2-5.9	17.7-28.0	140-159
22	Montan, crude	73-82		1.01-1.02*[25]	14-18	40-60	90-110
23	Montan, refined	80-86		1.01-1.03*[25]	10-14	40-60	90-110
24	Ouricury	81-86		0.998-1.069	6.2-23.8	12-20	80-100
25	Ozocerite, refined	73-75		0.907-0.920			
26	Palm	74-86		0.991-1.045*[15]	8.9-16.9[4]	5.0-10.6	64.5-104
27	Paraffin, American	49-63	1.422-1.448[80]	0.897-0.915*[14]			
28	Rice bran	75-83			8-19.4	15-17	57-104
29	Shellac	79-82		0.971-0.980	1.3-8.8[3]	0-5[6]	37-50[7]
30	Sisal hemp	74-81		1.007-1.010	22.3-33.3[4]	16-22.2	56-86.3
31	Sorghum	77-82			15.7-20.9	10-16	16-44
32	Spermaceti	42-50	1.440[70]	0.905-0.960	3.0-5.9	0-6.0	108-135
33	Sperm, body	3-46	1.462[30]	0.880-0.883	81-84	1.2	123-133
34	Sugarcane, crude	52-70		0.961-0.998[85]	10-40	8-45	50-120
35	Sugarcane, cuticle	74-81.5			8-15.6	7-24	24-57
36	Sugarcane, commercial	76-82	1.4435[90]	0.983[25]	8-20	8-23	55-106
37	Wool, refined	36-55	1.478-1.482[40]	0.904-0.945	15-47[3]	5-22	82-140

/1/ Superscripts indicate temperature at which measurement was made. /2/ For specific gravity, superscripts indicate temperature of measurement referred to that of water at the indicated temperature; where no superscript appears, the sp.gr. is that calculated to 15°C referred to water at 15°C. For density, superscripts indicate temperature at which determination was made. /3/ Wijs test. /4/ Hanus test. /5/ Hubl test. /6/ A range of 12-24.3 has been reported. /7/ A range of 64-126 has been reported.

14. PHOSPHATIDES, CEREBROSIDES, AND RELATED LIPIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

	Lipid	Formula	Melting Point °C	Specific Rotation[1] $[\alpha]_D$	Iodine Value	Solubility[1]
	Phosphatides					
1	Lecithins	$C_{10}H_{20}NPO_8RR'$		5.5-6.0 in chl.	33-127	v.s. al., eth., chl., bz., pet. eth., c. tet., c. disf.; i. actn., me. acet., par.
2	Lysolecithin	$C_9H_{21}NPO_8R$	100	-2.6 in chl.		v.s. al., eth., chl., pyr.; i. w., actn.
3	Cephalin (phosphatidyi-ethanolamine)	$C_7H_{12}NPO_8RR'$	174	13.6 in pet. eth.	40-80	v.s. chl., bz., pet. eth., c. disf., ac.a.; i. al., eth., acetn.
4	Phosphatidic acids	$C_5H_7PO_8RR'$				v.s. eth., actn., m. f. solv.; sl. s. w.
5	Cardiolipin	$C_5H_7PO_8RR'(?)$		5.8 in al.	99.8-126	v.s. al., actn., m. f. solv.; i. w.
6	Sphingomyelins	$C_{47}H_{97}N_2PO_7$	196-198	13.8 in pyr.	30.7	sl. s. al., pyr.; i. eth., actn.
7	Sphingosine	$C_{18}H_{37}NO_2$				v.s. al., actn.; sl. s. eth., pet. eth.; i. w.
8	Dihydrosphingosine	$C_{18}H_{39}NO_2$	60-61			
9	Lignocerylsphingosine	$C_{42}H_{85}NO_3$	156-157			v.s. eth., actn.
10	Plasmalogens	$C_5H_{12}NPO_6R$				v.s. chl., aq. KOH; sl. s. al., eth., pet. eth., actn.; i. w.
	Cerebrosides					
11	Ceranine	$C_{48}H_{93}NO_8$	180-187	-2.5 to -9 in pyr.	31.3	v.s. pyr.; sl. s. al., chl., bz., e. acet., ac. a., actn.; i. eth., pet. eth., w.
12	Phrenosine	$C_{49}H_{95}NO_9$	212	3.7 in pyr.	30.7	v.s. pyr.; sl. s. al., chl., bz., e. acet. ac. a., actn.; i. eth., pet. eth., w.
13	Nervone	$C_{48}H_{91}NO_8$	180	-4.3 in pyr.	62.7	v.s. chl., bz., e. acet., ac. a., actn., pyr.; sl. s. al.; i. eth., pet. eth., w.
14	Cerebronyl-N-sphingosine	$C_{42}H_{83}NO_4$	83-84		38.8	v.s. al., eth., actn.; i.w.
15	Dihydropsychosine	$C_{24}H_{49}NO_7$				v.s. al., actn.; i. eth., pet. eth., w.
16	Ganglioside	$C_{64}H_{118}N_2O_{26}$		-2.8 in pyr.		v.s. mixt. of chl. or bz. with al.; sl. s. al.; i. eth., e. acet., actn.
17	Pyschosine	$C_{26}H_{47}NO_7$	215			v.s. al.; i. eth., pet. eth.

/1/ ac. a.=acetic acid; actn.=acetone; al.=alcohol; aq. KOH=aqueous KOH; bz.=benzene; c. disf.=carbon disulfide; c. tet.=carbon tetrachloride; chl.= chloroform; e. acet.=ethyl acetate; eth.=ether; i.=insoluble; me. acet.=methyl acetate; m. f. solv.=most fat solvents; par.=paraldehyde; pet.=petroleum; pyr.=pyridine; sl.=slightly; s.=soluble; v.=very; w.=water.

Part I: ANIMAL STEROLS (ZOOSTEROLS)

	Common Name	Systematic Name[1]	Empirical Formula	Melting Point °C	Specific Rotation[2] $[\alpha]_D$	Source
	Vertebrate Sterols					
1	Cholesterol[3]	Δ^5-Cholesten-3β-ol	$C_{27}H_{46}O$	149	-39	All animal cells; spinal cord; wool grease.
2	7-Dehydrocholesterol[4]	$\Delta^{5,7}$-Cholestadien-3β-ol	$C_{27}H_{44}O$	148	-114	Cholesterol; skin of swine; snail.
3	7α-Hydroxycholesterol	Δ^5-Cholestene-3β, 7α-diol	$C_{27}H_{46}O_2$	157	-68	Sclerotic aorta; serum (pregnant mare).
4	7β-Hydroxycholesterol	Δ^5-Cholestene-3β, 7β-diol	$C_{27}H_{46}O_2$	178	+7.2	Liver (cattle, swine); serum (pregnant mare).
5	7-Ketocholesterol	Δ^5-Cholesten-3β-ol-7-one	$C_{27}H_{44}O_2$	157	-104	Testes (cattle; swine).
6	Dicholesteryl ether		$C_{54}H_{90}O$	196	-38	Spinal cord.
7		$\Delta^{3,5}$-Cholestadien-7-one	$C_{27}H_{42}O$	112	-305	Testes (swine); sclerotic aorta; spleen (swine).
8		$\Delta^{4,6}$-Cholestadien-3-one	$C_{27}H_{42}O$	80	+35	Sclerotic aorta; spleen (swine).
9	Cholestanol[3]	Cholestan-3β-ol	$C_{27}H_{48}O$	142	+24	Cholesterol; sclerotic aorta.
10		Cholestane-3, 6-dione	$C_{27}H_{44}O_2$	175		Testes (swine).
11		Cholestan-3β-ol-6-one	$C_{27}H_{46}O_2$	143		Spleen (swine).
12		Cholestane-3β, 5α, 6β-triol	$C_{27}H_{48}O_3$	239	+3.2	Liver (cattle); testes (swine); sclerotic aorta.
13		Cholestane-3β, 5α-diol-6-one	$C_{27}H_{46}O_3$	225		Cholesterol; liver (swine).
14		Δ^4-Cholesten-3-one	$C_{27}H_{44}O$	81	+89	Feces, hypophysis, testes (swine).
15		Δ^4-Cholestene-3β, 6β-diol	$C_{27}H_{46}O_2$	258	+9.0	Spleen (swine).
16	Coprostanol	Coprostan-3β-ol	$C_{27}H_{48}O$	101	+28	Feces.
17	Epicoprostanol	Coprostan-3α-ol	$C_{27}H_{48}O$	117	+32	Feces; ambergris.
18		Cholestan-3-one	$C_{27}H_{46}O$	63	+36	Ambergris.
19	Lathosterol[3]	Δ^7-Cholesten-3β-ol	$C_{27}H_{46}O$	122	+5.7	Skin; cbolesterol.
	Invertebrate Sterols					
20	Aptostanol		$C_{28}H_{50}O$	135	+22	Sponge.
21	Chalinasterol[5]	$\Delta^{5,22}$-24-iso-Ergostadien-3β-ol	$C_{28}H_{46}O$	144	-42	Sponge; oyster.
22	Clionasterol	$\Delta^{5,}$-24-iso-Stigmastien-3β-ol(?)	$C_{29}H_{50}O$	138	-37	Sponge.
23	Corbisterol	$\Delta^{5,7,24}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	151	-106	Corbicula leans.
24	Halicloasterol		$C_{28}H_{48}O$	141	-41.5	Sponge.
25	Neospongosterol	Δ^{22}-24-iso-Ergosten-3β-ol	$C_{28}H_{48}O$	153	+10	Sponge.
26	Palysterol		$C_{29}H_{50}O$	140	-47	Sea anemone.
27	Poriferasterol	$\Delta^{5,22}$-24-iso-Stigmastadien-3β-ol	$C_{29}H_{48}O$	156	-49	Sponge.

/1/ The numbers after the symbol Δ indicate the position of double bonds in the basic cyclopentenoperhydrophenanthrene ring. /2/ Chloroform solvent for most determinations. /3/ Also isolated from invertebrates. /4/ Provitamin D_3. /5/ Possibly identical with ostreasterol.

Part II: PLANT STEROLS (PHYTOSTEROLS)

	Common Name	Systematic Name[1]	Empirical Formula	Melting Point °C	Specific Rotation[2] $[\alpha]_D$	Source
1	Δ^5-Avenasterol	$\Delta^{5,11(?)}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	137	-37.6	Oats.
2	Δ^7-Avenasterol	$\Delta^{7,11(?)}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	145	+8.8	Oats.
3	Brassicasterol	$\Delta^{5,}$-24-iso-Ergosten-3β-ol	$C_{28}H_{48}O$	148	-64	Rapeseed; mussel.
4	Campesterol	$\Delta^{5,}$-24-iso-stigmasten-3β-ol	$C_{28}H_{48}O$	158	-33	Rapeseed; soybean; wheat germ.
5	Ergostanol	Ergostan-3β-ol	$C_{28}H_{50}O$	143	+16	
6	β-Sitosterol	Δ^5-Stigmasten-3β-ol	$C_{29}H_{50}O$	140	-36	Cottonseed; calycanthus seed; cinchona bark; wheat germ; rubber.
7	γ-Sitosterol	$\Delta^{5,}$-24-iso-Stigmasten-3β-ol	$C_{29}H_{50}O$	148	-43	Soybean; wheat germ; rye germ.
8	Dihydrositosterol	Stigmastan-3β-ol	$C_{29}H_{52}O$	140	+25	Grains.
9	α-Spinasterol	$\Delta^{7,22,}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	175	-2.7	Spinach; senega root; alfalfa; colocynth.
10		Δ^7-Stigmasten-3β-ol	$C_{29}H_{50}O$	145	+9	Wheat germ.
11	Stigmasterol	$\Delta^{5,22}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	170	-51	Calabar bean; soybean.
	Mycosterols					
12	Aacosterol	$\Delta^{8,23(?)}$-Ergostadien-3β-ol	$C_{28}H_{46}O$	147	+45	Yeast.
13	Cerevisterol	$\Delta^{7,22}$-Ergostadiene-3β, 5α, 6β-triol	$C_{28}H_{46}O_3$	254	-79	Yeast; ergot.
14	Chondrillasterol		$C_{28}H_{48}O$	168	-1.1	Green algae; sponge.
15	Episterol	$\Delta^{7,24(28?)}$-Ergostadien-3β-ol	$C_{28}H_{46}O$	151	-5	Yeast.
16	Ergosterol[3]	$\Delta^{5,7,22,}$-Ergostatrien-3β-ol	$C_{28}H_{44}O$	165	-130	Ergot; yeast; Aspergillus niger.
17	Dehydroergosterol	$\Delta^{5,7,9(11),22,}$-Ergostatetraen-3β-ol	$C_{28}H_{42}O$	146	+169	Yeast; ergot.
18	5-Dihydroergosterol	$\Delta^{7,22,}$-Ergostadien-3β-ol	$C_{28}H_{46}O$	174	-20	Yeast.
19	Fecosterol	$\Delta^{8,24(28?)}$-Ergostadien-3β-ol	$C_{28}H_{46}O$	162	+42	Yeast.
20	Fucosterol	$\Delta^{5,24(28)}$-Stigmastadien-3β-ol	$C_{29}H_{48}O$	124	-38	Brown algae.
21	Fungisterol	$\Delta^{7,}$-Ergosten-3β-ol	$C_{28}H_{48}O$	148	-0.2	Ergot.
22	Zymosterol	$\Delta^{8,24,}$-Cholestadien-3β-ol	$C_{27}H_{44}O$	108	+47	Yeast.

/1/ The numbers after the symbol Δ indicate the position of double bonds in the basic cyclopentenoperhydrophenanthrene ring. /2/ Chloroform solvent for most determinations. /3/ Provitamin D_2.

Part I: 24-CARBON ACIDS[1]

	Acid	Empirical Formula	Hydroxyl Groups	Melting Point °C	Specific Rotation $[\alpha]_D$	Sources
1	Bufodesoxycholic acid[2]	$C_{24}H_{40}O_4$				Toad.
2	Chenodesoxycholic acid	$C_{24}H_{40}O_4$	3a, 7a	140	+11	Man, coypu, guinea pig, ox, sheep, chicken, duck, goose, turkey, fish.
3	Cholic acid[3]	$C_{24}H_{40}O_5$	3a, 7a, 12a	196-198	+37	Man, antelope, bear, goat, ox, sheep, other mammals, duck, turkey, reptiles, salamander, fish.
4	Desoxycholic acid	$C_{24}H_{40}O_4$	3a, 12a	176-177	+53	Man, antelope, deer, dog, goat, ox, rabbit, other mammals, salamander.
5	3a, 12a-Dihydroxy-7-keto-cholanic acid	$C_{24}H_{38}O_5$	3a, 12a	263-264		Ox, snake.
6	7a, 12a-Dihydroxy-3-keto-cholanic acid	$C_{24}H_{38}O_5$	7a, 12a	181-182, ethyl ester		Ox.
7	3a-Hydroxy-$\Delta^{8(14)}$-cholenic acid	$C_{24}H_{38}O_3$	3a	160	+71	Chicken.
8	3a-Hydroxy-6-ketoallo-cholanic acid	$C_{24}H_{38}O_4$	3a	194		Swine.
9	3a-Hydroxy-7-ketocholanic acid ("nutricholic acid")	$C_{24}H_{38}O_4$	3a	201-203	-27	Coypu, guinea pig.
10	3a-Hydroxy-12-ketocholanic acid	$C_{24}H_{38}O_4$	3a	164-165	+110	Ox.
11	"α"-Hyodesoxycholic acid	$C_{24}H_{40}O_4$	3α, 6α	196-197	+8	Boar, swine.
12	"β"-Hyodesoxycholic acid	$C_{24}H_{40}O_4$	3β, 6α	189-190	+5	Swine.
13	3-Keto-$\Delta^{4,\,6}$-choladienic acid	$C_{24}H_{34}O_3$		150-152		Chicken.
14	"α"-Lagodesoxycholic acid	$C_{24}H_{40}O_4$	3, 12(?)	156-157	+80	Rabbit.
15	"β"-Lagodesoxycholic acid	$C_{24}H_{40}O_4$		213	+37	Rabbit.
16	Lithocholic acid	$C_{24}H_{40}O_3$	3a	184-186	+32	Man, ox, rabbit.
17	"β"-Phocaecholic acid	$C_{24}H_{40}O_5$	3, 7, 23(?)	222-223	+27	Seal, walrus.
18	Pythocholic acid	$C_{24}H_{40}O_5$	3a, 12, 16 or 15(?)	186-187	+28, methyl ester	Snake (Boidae)
19	Ursodesoxycholic acid	$C_{24}H_{40}O_4$	3a, 7β	203	+57	Coypu, bear.

/1/ Derivatives of cholanic acid, possibly excluding Items 1 and 15 (unknown structure) and Item 8 (possible allomerization product). /2/ Not cryatallized. /3/ Conjugates with glycine and taurine; glycocholic and taurocholic acids are bile acids most commonly found in man.

Part II: 27-AND 28-CARBON ACIDS[1]

	Acid	Empirical Formula	Hydroxyl Groups	Melting Point °C	Specific Rotation $[\alpha]_D$	Sources
1	Acid (unnamed)	$C_{27-28}H_{46-48}O_6$		255		Shark.
2	Sterocholic acid	$C_{28}H_{48}O_4$		256		Ox.
3	Tetrahydroxyisostero-cholanic acid	$C_{27-28}H_{46-48}O_6$		205		Turtle.
4	Tetrahydroxynorastero-cholanic acid	$C_{27}H_{46}O_6$	3a, 6a, 12, 24(?)	212-214	+27	Chicken, fish.
5	Tetrahydroxystero-cholanic acid	$C_{27-28}H_{46-48}O_6$	3a, 7a, 12a	150		Tortoise, turtle.
6	Trihydroxybufoisostero-cholenic acid	$C_{28}H_{40}O_5$	3a, 7a, 12a	227	+47	Toad.
7	Trihydroxybufostero-cholenic acid	$C_{28}H_{40}O_5$	3a, 7a, 12a	160	-13	Toad.
8	Trihydroxycoprostan-26-oic acid (originally "α"-trihydroxybianorsterocholanic acid)	$C_{27}H_{46}O_5$	3a, 7a, 12a	172	+22	Crocodile, frog.
9	Trihydroxycoprostan-27-oic acid (originally "β"-trihydroxybianorsterocholanic acid)	$C_{27}H_{46}O_5$	3a, 7a, 12a	195-196		Frog.
10	Varanic acid	$C_{27}H_{46}O_6$		120		Lizard.

/1/ Only Items 8 and 9 are of completely determined structure.

	Protein	Source	Unit Cell Dimensions (Å units), a	b	c	Space Group, β	Molecular Weight, MW	Method	Sedimentation Constant[2]	Partial Specific Volume[3]	Protein Crystal Density[5]	Isoelectric pH[6]
1	Actin, G-	Rabbit muscle					40,000	l	3.7			4. 5
2	Adrenocorticotropic hormone	Sheep pituitary					20,000	sd	2. 0	0.757		4. 6-4. 7(0. 1)
3	Aldolase	Rabbit muscle					147,000	sd(?)	7. 9	0. 740		8. 5(0. 0)
4	Amsndin	Almond					208,000	e	11. 4	0. 746		
5	Amylase, α	Barley malt					60,000	o				6
6	Amylase, β	Sweetpotato					150,000	sd	8. 9	0. 7497		4. 7(0. 1)
7	Antitoxin, diphtheria	Horse plasma					180,000	sd	7. 2	0. 7457		6. 0
8	Bence-Jones	Human urine[8]					36,009	e;sd	3. 55	0. 749		4. 3-4. 7
9	Bushy stunt virus	Tomato[8]	386			I (cubic)	10, 800, 000	x	132	0. 739		4. 11(0. 02)
10	Carbonic anhydrase	Beef blood					30,000	sd	2. 8	0. 7497		5. 3(0. 1)
11	Carboxypeptidase	Beef pancreas					33,000[10]	sd;vd	3. 07	0. 757		6. 0(0. 2)
12	Cardiotoxin	Cobra venom					46,000	d		0. 757		
13	Casein (kaseinogen)	Cow milk					33,600	o	10. 4	0. 728		4. 6
14	Catalase	Human blood					220,000	s;a	11. 2	0. 737		
15	Chorionic gonadotropin	Human urine[11]					100,000	sd	4. 3	0. 76		
16	Chymotrypsin, α	Beef pancreas	49. 6	67. 8	66. 5	102° $P2_1$	22,500	sd;av	2. 5	0. 73		8. 1(0. 1)
17	Chymotrypsinogen, α	Beef pancreas					22,500	sd;av	2. 5	0. 72		9. 5(0. 01)
18	Colostrum globulin, immune	Cow colostrum					175,000[12]	d	7			5. 85(0. 1)
19	Conalbumin	Chicken egg white					74,000	a				6. 8(0. 1)
20	Concanavalin A	Jack bean					96,000	sd	6. 0	0. 73		
21	Crotoxin	Rattlesnake venom					30,000	e;sd	3. 1	0. 704		4. 7(0. 1)
22	Cytochrome-c	Beef or horse heart					16,000	sd	1. 9	0. 707		10. 65[13](0. 1)
23	Edestin	Hemp seed					310,000	sd	12. 8	0. 745	1. 29-1. 32	5. 5[14]
24	Excelsin	Brazil nut	86		208. 2^{15}	R3	295,000	sd	11. 8	0. 743	1. 285	
25	Fetuin	Fetal calf blood					50,000	sd	3. 1-3. 4	0. 70		3. 5(0. 2)
26	Fibrinogen	Human blood					500, 000[16]	o;sv	9			5. 4(0. 1)
27	Gelatin	Collagenous tissues					Variable[17]	o				4. 9(0. 01)
28	Gliadin	Wheat					27,000	e	2. 1	0. 71		6. 5[14]
29	Globin	Horse blood					37,000	sd	2. 5	0. 749		7. 5(0. 1)[18]
30	Globulin, α	Barley					26,000	sd	2. 5	0. 72		5. 0(0. 1)
31	Globulin, γ	Barley					170,000	sd	8. 3			5. 7(0. 1)
32	Gluten	Wheat					39,000[19]	e	2. 5	0. 700		7
33	Growth hormone	Beef pituitary					47,000[20]	s;sd	3. 6	0. 76		6. 85(0. 1)
34	Hemocyanin	Helix pomatia					8,900,000	sd	103	0. 738		5. 05(0. 02)
35	Hemoglobin	Human blood	109	63. 2 $C2^{21}$	54. 4	111°	66, 700[22]	sd	4. 5	0. 749	1. 16	6. 87(0. 1)
36	Hexokinase	Baker's yeast					97,000	sd	3. 1	0. 7407		4. 5-4. 8(0. 02M)[23]
37	Insulin	Beef pancreas	83		34	R3[24]	36,000	o;sd	3. 5	0. 749	1. 28	5. 2(0. 033)
38	Lactalbumin, α	Cow milk					17,500	sd	1. 9			
39	Lactogenic hormone	Beef, sheep pituitary					26,500	o				5. 7(0. 05)
40	Lactoglobulin, β	Cow milk	89. 2	129. 0	42. 1	156. 47 $P2_12_12_1$	35,400	x	3. 12	0. 751	1. 146	5. 1(0. 1)
41	Lactoglobulin, immune	Cow milk					180,000	sd	7			5. 8(0. 1)
42	Lysozyme chloride	Chicken egg white	79. 1		37. 9	$P4_12_1$	13,900	x	2. 1	0. 722	1. 233	11. 35(0. 1)
43	Metakentrin	Sheep pituitary					40,000	o;a	3. 6			4. 6(0. 1)
44	Myosin	Rabbit muscle					850,000	sd;o	7. 1			5. 4(0. 1-0. 5)
45	Ovalbumin	Chicken egg white					44,000	sd	3. 55	0. 749	1. 24-1. 27	4. 58(0. 1)
46	Pepsin	Hog gastric mucosa	67. 9		292	$C6_12$	36,000	x	3. 3			2. 75-3. 0
47	Relaxin	Pregnant sow ovary					9,000	s;s				
48	Ribonuclease	Beef pancreas	30. 90	38. 80	54. 06	106° $P2_1$	13,400	x	1. 85	0. 709	1. 220	7. 8(0. 055)
49	Ricin	Castor bean					80,000	sd	4. 8	0. 757		5. 2-5. 5
50	Salmine	Salmon testes					7,000	a	<1			12
51	Serum albumin	Human blood	178. 2^{25}	54. 2^{25}	166. 2^{25}	91° C2	65,600	x	4. 6	0. 733	1. 145	4. 9
52	Serum globulin, α_1	Human blood					200,000	sv	5. 0	0. 841		
53	Serum globulin, β_1	Human blood					90,000	sv	5. 5	0. 725		
54	Serum globulin, γ	Human blood					160,000	sv	7. 2	0. 739		5. 7(0. 1)[26]
55	Serum globulin, γ_1, anti-pneumococcus	Human blood					190,000	sd	7. 4	0. 7457		5. 6(0. 1)[27]
56	Thymus nucleohistone	Calf thymus					2,000,000	e;sd	31. 0	0. 658		4. 58(0. 02)
57	Thyroglobulin	Hog thyroid					700,000	sd	19. 2	0. 72		3. 49(0. 02)
58	Tobacco mosaic virus	Tobacco leaves[8]					40,000,000	x	185	0. 72		
59	Toxin, botulinum, type A	Cl. botulinum					900,000	sd	17	0. 75		
60	Toxin, botulinum, type B	Cl. botulinum					60,000	d				4. 1(0. 005)[23]
61	Toxin, diphtheria	C. diphtheriae					74,000	sd	4. 6	0. 736		
62	Toxin, tetanus	Cl. tetani					67,000	s;s	4. 5			
63	Trypsin	Beef pancreas					20,700	a				10. 8(0. 03M)
64	Trypsio inhibitor	Beef pancreas	111		122	$C6_32$	6,000	o				
65	Tuberculin protein	M. tuberculosis					32,000	sd	3. 3			4. 3(0. 03)
66	Tyrosinase	Ps. campestris					100,000	sd	6. 4	0. 757		<5
67	Urease	Jack bean					480,000	sd	18. 6	0. 73		5. 0(0. 012)[14]
68	Yellow enzyme, "old"	Brewer's yeast					80,000	sd;e	5. 8	0. 731		5. 22(0. 02)
69	Zein	Maize					40,000	sd	1. 9	0. 737		

/1/ From X-ray data. Wet preparation, unless otherwise noted. /2/ The code describing the method used is: s=chemical analysis or combining ratio; d=diffusion constant; e=sedimentation equilibrium; l=light scattering; o=osmotic pressure; a=sedimentation velocity; v=intrinsic viscosity; x=X-ray diffraction. /3/ Specific sedimentation velocity in units of 10^{-13}. /4/ Cubic centimeters increase in volume of solution per gram of protein dissolved. /5/ Grams per cubic ceotimeter, wet. /6/ pH at which protein does not move in an electric field. The ionic strength is given in parentheses. /7/ Assumed value. /8/ Pathological. /9/ 35, 000-37, 000. /10/ 32, 000-34, 000. /11/ During pregnancy. /12/ 160, 000-190, 000. /13/ At 0°C for the oxidized (ferri) form. /14/ Based on solubility minimum. /15/ Dry. /16/ 400, 000-580, 000. /17/ 5, 000-400, 000. /18/ For human globin. /19/ To 4, 600, 000. /20/ 44, 000-49, 000. /21/ Met-co-oxyhemoglobin I (horse). /22/ Same value also for oxy-, met-, and carboxyhemoglobin. /23/ By cataphoresis. /24/ Crystalline modification of insulin (Scott-Zn) with molecular weight of 5734. /25/ Dimensions of a pseudo-orthogonal unit cell with all faces centered. /26/ Depends on fraction employed. /27/ Hyperimmune horse blood.

18. PLASMA PROTEINS, ELECTROPHORETIC ANALYSIS: MAMMALS AND BIRDS

Veronal-citrate buffer, pH 8.6; ionic strength 0.1. Values are mobilities (m = sq cm per sec per volt x 10^5) and percentages of total protein.

	Species	Component																	
		Fast[1]		Albumin		Globulin													
						α_1		α_2		α_3		β		ϕ		γ	
		m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%
1	Man			6.6	59.6	5.4	6.7	4.3	8.8				3.1	11.0		2.3	4.8	1.3	9.1
2	Cat			7.7	41.4	6.3	8.1	5.2	20.2	4.1	4.7	3.4	8.7		2.6	5.2	1.6	12.5
3	Cow			7.0	40.6	5.5	10.7	4.7	8.3			3.7	13.7		2.6	16.3	1.4	11.0
4	Dog			6.8	39.6	5.7	16.9	4.4	8.0			3.3	13.0		2.4	13.3	1.2	9.3
5	Fox			7.5	47.1	6.4	10.2	5.2	7.8						3.2	11.2	1.3	3.9
6	Goat			7.3	49.2	5.6	13.7	4.1	12.7				3.1	3.9	2.5	7.6	1.5	12.9
7	Guinea pig			6.1	54.6	5.4	4.0	4.9	3.7	4.4	15.2	3.0	8.8		2.1	8.1	1.0	5.6
8	Horse	7.9	0.8	7.1	29.8	6.2	4.8	4.8	12.3			3.7	21.9		2.5	15.8	1.4	11.2
9	Mink			4.9	51.5	4.2	11.7	3.8	9.8			3.7	10.3		3.2	5.0	2.2	12.1
10	Monkey	7.4	0.5	6.6	50.0	5.4	5.9	4.8	5.2	4.2	4.7	3.3	16.1		2.2	8.4	1.4	9.0
11	Rabbit			6.8	63.3	5.1	11.5					3.5	13.0		2.4	7.9	1.4	4.3
12	Rat	7.1	1.3	6.1	59.1				15.4						2.7	19.4	1.6	4.8
13	Sheep			6.8	43.7	5.3	9.8	4.3	6.7			3.4	15.0		2.6	9.7	1.6	15.0
14	Swine	7.3	0.4	6.5	39.9	5.2	6.0	4.4	16.3			3.7	8.2		2.8	13.9	1.8	15.2
15	Chicken	7.5	0.6	6.8	40.4	5.4	14.9	4.1	11.3								2.5	32.8
16	Duck	7.6	2.6	6.7	47.8	5.8	21.9	4.9	6.1						3.7	15.5	2.5	6.0
17	Pheasant	6.1	0.4	5.2	58.5	4.2	14.0	3.6	5.5						2.9	16.3	1.7	4.3
18	Pigeon	7.8	3.1	6.4	64.1	5.2	7.2	4.5	4.5						3.3	17.4	1.7	7.7
19	Turkey	6.7	1.0	5.9	51.5	5.0	13.4	4.1	4.3						2.9	21.6	1.7	8.1

/1/ A component on the leading shoulder of the albumin peak.

19. SERUM PROTEINS, ELECTROPHORETIC ANALYSIS: REPTILES, AMPHIBIANS, FISH, AND INVERTEBRATES

Veronal buffer, pH 8.6; ionic strength 0.1. Values are mobilities (m = sq cm per sec per volt x 10^5) and percentages of total protein.

	Species	Component																					
		1		2		3		4		5		6		7		8		9		10			
		m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%
1	Rattlesnake, diamond back	1.7	4.4	2.6	5.9	3.2	6.0	3.7	21.0	4.3	8.7	4.7	3.9	5.3	8.7	5.8	4.0	6.3	4.6	7.3	32.8		
2	Rattlesnake, timber	3.4	3.8	3.7	3.5	6.2	19.7	7.4	13.4	8.7	8.8	8.0	13.3	11.0	10.3	12.4	28.4	14.0	2.8				
3	Snake, milk	1.4	1.3	2.0	5.7	2.6	16.4	3.4	11.6	3.8	5.9	4.4	5.8	5.1	11.9	6.5	23.8	7.9	17.6				
4	Snake, water	3.8	16.6	4.1	17.9	5.7	30.7	6.9	5.0	7.6	10.3	8.8	3.5	10.0	6.6	11.7	9.4						
5	Snake, water moccasin	1.0	2.5	1.8	15.8	2.8	18.8	3.9	13.5	4.5	5.4	5.0	5.3	5.7	13.3	6.4	6.4	6.8	5.4	7.4	15.6		
6	Turtle, snapping	1.1	5.3	1.8	20.5	3.8	31.5	3.6	16.6	4.5	7.5	5.3	16.2	6.1	2.4								
7	Turtle, soft-shelled	1.4	1.9	2.5	15.5	3.5	11.6	4.4	17.6	5.8	51.8	6.9	1.6										
8	Frog, bull	1.5	8.4	2.3	7.0	3.1	5.5	3.7	5.8	4.3	12.0	4.9	22.4	5.6	16.0	6.5	22.4	7.2	0.5				
9	Bass, rock	2.3	1.3	3.0	5.7	3.6	2.9	4.3	9.3	5.4	24.2	6.1	17.3	7.0	10.7	7.9	27.9	8.8	0.7				
10	Buffalo-fish	1.4	2.5	2.5	25.0	3.1	10.2	3.9	9.7	4.7	17.8	5.4	5.5	6.2	5.5	6.9	23.8						
11	Bullhead	1.8	0.6	3.0	4.7	4.0	8.5	5.4	15.8	6.8	7.3	7.6	9.3	8.7	30.6	10.0	23.4						
12	Carp	2.3	4.1	3.7	8.2	4.7	14.3	5.7	15.0	7.1	21.5	8.6	36.9										
13	Catfish, channel	1.3	2.9	1.8	3.8	2.3	3.2	3.0	6.6	3.9	6.6	4.7	11.2	5.7	20.6	6.5	45.1						
14	Catfish, eel, willow cat	1.7	6.2	2.3	7.8	3.1	4.3	3.7	5.1	4.4	14.1	5.6	32.4	6.7	4.2	7.7	25.9						
15	Perch, yellow	2.5	1.8	2.9	2.6	3.5	7.0	4.4	4.6	5.0	16.6	5.8	8.8	6.5	4.4	7.2	5.2	8.0	7.0	8.7	11.0[1]		
16	Pike, northern	1.9	7.8	2.8	12.2	3.7	6.3	4.3	7.8	5.7	48.2	8.0	13.5	8.7	4.2								
17	Sucker	1.4	1.4	2.1	13.6	3.0	14.2	3.8	12.1	4.9	18.7	5.5	7.6	6.4	31.8	7.4	0.6						
18	Sturgeon, rock	1.7	22.6	2.3	8.5	3.0	10.4	3.6	5.6	4.3	5.3	5.0	18.3	5.6	11.5	6.2	8.9	6.9	7.4	7.4	1.5		
19	Trout, lake	1.3	1.4	2.2	3.8	2.7	7.9	3.4	6.5	4.2	8.2	4.9	12.8	6.5	58.4	7.5	1.0						
20	Trout, rainbow	1.3	1.2	2.0	1.6	2.7	3.4	3.1	4.2	4.2	34.7	5.1	6.7	6.3	45.6	7.4	2.8						
21	Whitefish	1.3	0.5	2.7	7.5	3.0	11.7	3.5	12.7	4.1	8.1	4.8	14.6	5.7	12.1	5.9	17.6	7.0	14.7	7.7	0.5		
22	Crab, horseshoe	2.0	4.0	4.5	7.5	5.1	10.7	6.1	24.5	6.7	53.3												
23	Snail, land	2.4	2.7	3.5	2.0	4.7	4.8	6.2	7.0	7.1	13.6	7.9	62.3	9.5	7.6								

/1/ Eleventh and twelfth components with m and % of 9.7, 29.8, and 10.8, 1.2, respectively, were also found.

20. PLASMA PROTEINS, PROPERTIES AND REACTIONS: MAN

	Protein Component	Electrophoretic Fraction	Interacts with:	General Properties
1	Albumin	Albumin	Fatty acids, bile salts, dyes	Osmotic regulation of blood volume.
2	α_1-Lipoproteins	α_1- globulin	Steroids	35% lipid.
3	Antibody euglobulin	γ_1-globulin	Antigens	Typhoid "O" and other agglutinins.
4	Antibody γ-globulin	γ-globulins	Antigens	Antibodies for pathogenic organisms.
5	Antihemophilic globulin			Necessary for clotting of hemophilic blood.
6	β_1-Lipoproteins	β_1- globulin	Steroids	Carrier for vitamins, hormones, triglycerides.
7	Bradykininogen	α_2- globulin	Tryptic enzymes	Bradykinin precursor.
8	Cholinesterase		Choline esters	
9	Complement components C'_1, C'_2	α- and β- globulins	Antigen-antibody complex	
10	Fibrinogen		Thrombin	Forms fibrin clot.
11	Hypertensinogenin	α_2- globulin	Renin	Hypertensin precursor.
12	Isoagglutinins	γ-globulins	Incompatible red blood cells	Anti-A, anti-B, anti-Rh agglutinins.
13	Peptidase		L-Leucylglycylglycine	
14	Phosphatase, alkaline		Phosphoric acid monoesters	
15	Plasmin		Proteins	Digests protein, fibrin clots.
16	Plasminogen		Streptokinase	Enzyme precursor.
17	Prothrombin		Thromboplastin	Enzyme precursor.
18	Siderophilin	β- globulin	Fe^{+++}	Iron transport.
19	Thrombin		Fibrinogen	Catalyzes formation of fibrin clot.
20	Thyrotropic hormone	α- globulin		Influences thyroid activity.

Enzymes listed were either crystalline or electrophoretically homogeneous. Values are grams per 100 grams enzyme.

	Enzyme	Elements						Amino Acids																
		C	H	N	S	P	Other Elements	Alanine	Arginine	Aspartic Acid	Cysteine	Cystine [1]	Glutamic Acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenyl-alanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine
1	Alcohol dehydrogenase	52.8	6.96	16.54	1.21	Trace	Trace(Fe)																			
2	Aldolase			16.8				8.56	6.33	9.7		1.12	11.4	5.61	4.21	7.87	11.5	9.54	1.17	3.06	5.71	6.57	7.1	2.31	5.31	7.40
3	α-Amylase, human pancreas			15.8	0	0.01																				
4	α-Amylase, human saliva			15.52	0	0.01																				
5	α-Amylase, swine pancreas	49.46	7.18	15.52	1.33	0.05																				
6	α-Amylase, barley malt			13.4		0.01	0.035(Fe)																			
7	β-Amylase, sweetpotato			15.1					6.0			0.79[1]							4.32					7.0	
8	Carbonic anhydrase			15.9			0.33(Zn)					1.3													4.1	
9	Carboxypeptidase, pancreatic	52.6	7.2	14.4	0.47	0	0.18(Zn)	5.16	5.06	11.7		1.40[2]	10.7	5.06	3.47	7.65	9.41	7.81	0.44	7.16	3.66	10.1	9.21	3.62	10.3	5.58
10	Catalase, horse blood			16.8			0.093(Fe)		8.75	16.5		1.65[2]	10.9		4.17			7.50							6.0	
11	Catalase, horse liver			16.8			0.093(Fe)		8.90	16.5		1.85[2]	10.3		3.86			6.91							5.8	
12	Catalase, human blood			16.7			0.077(Fe)																			
13	α-Chymotrypsin	50.0	7.06	15.5	1.85	0	0.16(Cl)				1.22	3.66			1.26		9.1		1.25				11.2	5.81	2.83	
14	β-Chymotrypsin			16.24	1.56						1.29	3.51			1.22		9.4		1.29				10.6	6.40	2.87	
15	γ-Chymotrypsin			16.00	1.59						1.27	3.59			1.26		8.5		1.28				10.7	6.27	3.09	
16	Chymotrypsinogen	50.6	7.0	15.8	1.9	0	0.17(Cl)		2.82	11.3	1.29	3.30	9.0	5.3	1.23	5.7	10.4	8.0	1.22	3.6	5.9	11.4	11.4	5.57	2.96	10.1
17	Cytochrome - c	52.52	7.76	15.36	1.47	0	0.43(Fe)		5.6[3]			1.4[3]			6.3[3]			30.8[3]							1.4[3]	3.5[3]	
18	Deoxyribonuclease	50.16	6.91	14.88	1.09	0																				
19	Enolase	53.62	7.55	17.34	0.38	0																				
20	α-Glyceraldehyde phosphate dehydrogenase[4]	52.54	7.51	16.41	1.08	Trace		6.72	5.23	12.4		1.09	6.8	6.03	5.01	9.1	6.78	9.42	2.70	5.55	3.67	7.7	7.2	2.05	4.57	12.0
21	Hexokinase	52.16	7.08	15.62	0.91	0.11																				
22	Lecithinase	50.77	6.41	15.88	4.0				4.7	6.2	0	0	10.4	6.3	3.6	8.1	11.4	7.8	1.8	4.9	5.1		8.9	0.41	6.2	7.8
23	Lipoxidase							6.0	12.9	18.2		8.0[2]	4.3	5.7	1.05	5.3	8.4	5.9	2.0	3.1	1.4	7.0	5.4	10.6	3.7	4.7
24	Lysozyme			18.6	2.53			5.63	7.75	11.3		4.58[2]	12.4	8.41	0.85	6.05	6.10	5.67		3.16	5.11	5.91	3.89	4.68	14.7	8.43
25	Papain			15.5	1.2	0			1.0	16.0	0.5	1.64	11.9	6.4	0.9	10.8	10.4	0.9	1.7	6.4	5.0	12.2	9.6	2.36	8.5	7.1
26	Pepain, cattle	51.7	6.86	14.6	0.94	0.09																				
27	Pepsin, salmon	51.9	6.48	15.62	1.58	0.03																				
28	Pepsinogen	52.8	6.88	15.9	0.09																					
29	Peptic inhibitor[5]	48.1	8.07	16.65					31[3]															0	0.4[3]	
30	Peroxidase	47.0	7.35	13.2	0.43		0.13(Fe)		6.91						0.71			4.06								
31	Phospho-enoltrans-phosphorylase, human	53.35	7.30	17.40	1.60	0.06																				
32	Phosphorylase, rabbit muscle			16.5				4.79	11.6	9.3		0.45	13.4	3.8	3.3	6.5	10.5	7.2	2.7	6.2	4.7	3.05	4.24	2.0	5.9	7.3
33	Polypeptidase, yeast			13.5		0.3																				
34	Pyrophosphatase, yeast	54.46	7.36	16.25	0.14	0		4.9	3.3	12.1			9.7	2.9	2.2	8.9	6.0	10.9	1.3	6.2	6.4	3.1	4.8	3.6	6.0	4.1
35	Rennin	51.4	7.19	14.51	1.46	0.04	0.0035(Cu)																			
36	Ribonuclease	48.2	6.2	16.1	1.1	Trace		7.67	4.94	15.0		7.0	12.4	1.64	4.22	2.67	2.02	10.5	4.0	3.51	3.94	11.4	8.90		7.60	7.49
37	Trypsin	50.2	6.6	16.13	1.1	0	2.85(Cl)																	3.65	7.8	
38	Trypsinogen	50.1	6.9	15.3	1.1																					
39	Tryptic inhibitor[5], soybean	51.95	7.16	16.74	0.97	0																		2.2	4.0	
40	Tyrosinase			13.6			0.25(Cu)																			
41	Urease	51.6	7.1	16.0	1.2																					
42	Verdoperoxidase			17.15			0.1(Fe)																			
43	"Yellow enzyme, old"	51.4	7.07	16.27	0.48	0.043			8.25			0.34		7.1	2.75			13.7		5.75				4.86	7.75	

/1/ Cysteine plus cystine. /2/ Cystine. /3/ Per cent of total nitrogen. /4/ Element analysis refers to yeast enzyme; amino acid composition to rabbit muscle enzyme. /5/ Not an enzyme in the strict sense of the term.

	Enzyme	Source	Molecular Weight	Isoelectric pH	Solubility[1] g/100 ml	Absorption Maximum mμ	Optical Rotation[2] $[\alpha]_D^{25}$	Reaction Velocity Constants: Substrate	Temp °C	pH	Turnover Number[3]	K_a[4] Molarity
1	Alcohol dehydrogenase	Yeast	70,000					Ethanol, DPN	20	8.2	18,000	
2	Aldolase	Rat muscle	147,000	5.7	s.w.			Fructose-1,6-diphosphate	25	7.1	10,100	1.2×10^{-3}[5]
3	α-Amylase	Human saliva		5.0-5.5	0.3 at pH 8.5			Starch				4.8×10^{-3}
4	α-Amylase	Human pancreas			0.3 at pH 8.5							
5	α-Amylase	Swine pancreas	45,000	4.6-5.2	6 at pH 8.5							
6	α-Amylase	Malt, barley	60,000	5.7	10 at pH 8.5; sl. 40%			Starch	25	4.7		0.078%
7	β-Amylase	Sweetpotato	150,000	4.7-4.8								
8	Carbonic anhydrase	Red cells, mammalian	30,000	5.3				CO_2	0	7.3		9×10^{-3}
9	Carboxypeptidase	Cattle pancreas	33,000	5.95	i. w.			Benzenesulfonyl glycyl-phenylalanine	25	7.5		1.4×10^{-2}
10	Catalase	Cattle liver	225,000	5.7	s. w.	405		H_2O_2	25.5	7.0	120,000,000[6]	27
11	Catalase	Horse liver	225,000	5.4		405		H_2O_2	23-25	6.7	210,000,000[6]	37
12	Catalase	Human blood	220,000			405		H_2O_2	18	6.8	135,000,000[6]	
13	α-Chymotrypsin	Cattle pancreas	22,500	8.1-8.6	v. s. w.		-0.40°/mg N	Benzoyl-L-phenylalanine methyl ester	25	7.8	3,060	
14	α-Chymotrypsinogen	Cattle pancreas	22,500	9.5	sl. s. w.		-0.48°/mg N					
15	Desoxyribonuclease	Cattle pancreas	60,000	5.0	s. w.	280						
16	Diaphorase	Swine heart	70,000			274, 359, 451		2,6-Dichlorophenol-indophenol		8.5	2,700	1.2×10^{-4}
17	Enolase	Brewers' yeast	66,000[8]					2-Phosphoglycerate	20	7.34	6,500	
18	Fumarase	Swine heart	204,000	5.0-5.4				Fumarate	25	7.4		
19	Glutamic dehydrogenase	Cattle liver	1,000,000	4-5	i. w. (low pH)	279		Glutamic acid	Room	7.6	30,000	1.37×10^{-3}
20	α-Glycerophosphate dehydrogenase	Yeast	120,000	4-7	sl. s. w.	280		Dihydroxyacetone phosphate	22	7	26,500	
21	Hexokinase	Yeast	97,000	4.5-4.8	s. w.			Glucose	30	8.0	13,000[9]	1.6×10^{-4}
22	Lactic dehydrogenase	Rat liver	126,000	6.3	s. w., dil. salt sol.			Lactate, DPN	25	7.0	12,800	
23	Lactoperoxidase	Milk	82,000	8.05	a. dil. salt sol.	280, 412		H_2O_2	25	7.0	1,500	10^{-8}
24	Lipase	Swine pancreas						Methyl butyrate	25-28	7.0		9×10^{-2}
25	Lipoxidase	Soybean	102,400	5.4	s. dil. salt sol.	280		Linoleate	20	9.0	21,600	1.35×10^{-3}
26	Lysozyme	Egg	13,900	11.35	sl. s. w.							
27	N_2 fixing system	Azotobacter						Nitrogen	32	7.0	18	2×10^{-2}[10]
28	Papain	Papaya latex	27,000[8]	9-9.5	s. w., sl. 70%							
29	Pepsin	Cattle	36,000	2.7	s. w.	280	-71°/gram	Carbobenzoxy-l-glutamyl-l-tyrosine ethyl ester	38	4.0	0.18	1.9×10^{-3}
30	Pepsinogen	Cattle	42,000[11]				-61°/gram					
31	Peroxidase	Horseradish	44,100	7.2				H_2O_2	25	4.1		4.5×10^{-7}[12]
32	Phosphoglucomutase	Rabbit muscle				278		Glucose-1-phosphate	30	7.5	16,800	
33	Phosphorylase	Muscle	375,000[13]	5.8	s. salt sol.			Glucose-1-phosphate	30	6.7	9,000	2.6×10^{-3}
34	Pyrophosphatase	Yeast	100,000	4.75	s. w.							
35	Pyruvate kinase	Muscle						Phosphopyruvate	20	6.77	6,000	
36	Rennin	Calf gastric juice	40,000	4.5-4.65	sl. s. w.							
37	Ribonuclease	Cattle pancreas	13,400	7.8	s. w.	280	-0.47°(5%)					
38	Trypsin	Cattle pancreas	20,700	10.8	v. s. w.		-0.27°/mg N	Benzoyl-L-arginine ester	25	7.7	1,610	8×10^{-5}
39	Trypsinogen	Cattle pancreas	34,000	9.3								
40	Tyrosinase	Wild mushroom	100,000		i. dil. a., salt sol.	273, 330		Tyrosine	25	6.0		8×10^{-4}[14]
41	Urease	Jack bean meal	480,000	5.0-5.1				Urea	20	7.1	460,000	4×10^{-3}
42	"Yellow enzyme, old"	Yeast	80,000	5.22								

/1/ Abbreviations: a.=acid; al.=alcohol (ethyl, 95%); dil.=dilute; i.=insoluble; s.=soluble; sl.=slightly; v.=very; w.=water. Underlined superscripts represent temperature at which solubility was determined. /2/ In water at concentration shown at 25°C. /3/ Moles of substrate decomposed by one mole of enzyme per minute. /4/ Michaelis constant. /5/ K_a determined at pH 8.6 and 38°C. /6/ True only under the hypothetical condition that the concentrations of substrate and enzyme are the same and constant. /7/ Ratio of two consecutive reaction constants of enzyme with substrate. No true Michaelis-Menten constant exists. /8/ ≥2000. /9/ For glucose. /10/ Expressed in atmospheres. /11/ ≥3000. /12/ Range $4.1-5.0 \times 10^{-7}$. /13/ Estimated range 340,000-400,000. /14/ K_a is for tyrosinase from Neurospora sp.

	Enzyme	Co-factors[1]	Reactions Catalyzed[1]	Conditions Suitable for Enzyme Action[2]			Occurrence
				pH	Substrate Concentration	Temp. °C	
1	Aconitase	Fe^{++}	Citric acid→cis-aconitic acid→isocitric acid	7.4	0.03 M	25	Tissues; bacteria; yeasts; seeds; leaves.
2	Adenosinetriphosphatase	Ca^{++}	ATP→ADP + PO_4	7.5	1 mg P/ml	37	Brain; muscle; venoms; potatoes.
3	Aldolase	Co^{++}, Fe^{++}, or Zn^{++}	Fructose-1, 6-diphosphate→triosephosphates	9	0.01 M	38	Muscle; E. coli; yeasts; higher plants.
4	Amino tripeptidase		Tripeptides→dipeptide + amino acid	8.0	0.05 M	39	Mucosa; muscle.
5	α-Amylase (animal)	NaCl	Starch or glycogen→dextrins + maltose	7	1%	37	Liver; saliva; urine.
6	α-Amylase (plant)		Starch or glycogen→dextrins + maltose	4.5-5.5	12 mg/ml	30	Bacteria; yeasts; cereals.
7	β-Amylase (animal, plant)		Starch→dextrins + maltose	4-5	12 mg/ml		Cereals; soybeans; sweetpotatoes.
8	Amylosucrase		Sucrose→"glycogen" + fructose	5.6	10 mg/ml	23	Bacteria.
9	Apyrase	Ca^{++}	ATP→AMP + 2 phosphate	6.5		30	Liver; muscle; yeasts; tubers.
10	Arginase	Co^{++}, Mn^{++}	L-Arginine→L-ornithine + urea	9.5	0.66%	38	Liver; bacteria; fungi; seeds; spleen.
11	Asparaginase		L-β-Asparagine→L-aspartic acid + NH_3	8	0.5 M	40	Liver; mucosa; bacteria; fungi; seeds.
12	Aspartase		L-Aspartic acid→fumaric acid + NH_3	7-7.5	0.1 M	37	Bacteria; yeasts; leaves.
13	Carbonic anhydrase		$H_2CO_3 \rightarrow CO_2 + H_2O$	5-9	0.08 M	15	Erythrocytes; gastric mucosa.
14	Carboxylase, amino acid	Pyridoxal phosphate	Amino acid→amines + CO_2	4-5.5	0.001 M	30	Liver; kidney; pancreas; bacteria; higher plants.
15	Carboxylase, oxalacetic	Mn^{++}	Oxalacetate→pyruvate + CO_2	5.0	0.5 mg/L	30	Liver; bacteria; seeds; leaves.
16	Carboxylase, pyruvic	Thiamine pyrophosphate Mg^{++}	Pyruvate→acetaldehyde + CO_2	6.0	0.15 M	30	Fungi; bacteria; seeds.
17	Carboxylase, succinic		Succinic acid→propionic acid + CO_2				Bacteria.
18	Carhoxypeptidase		Peptide (free COOH)→amino acid + peptide	8.5	6% edestin	25	Pancreas (as zymogen).
19	Catalase		$H_2O_2 \rightarrow H_2O + O_2$	6.8	0.01 N	0	Erythrocytes; liver; kidney; hacteria; higher plants.
20	Cellulase		Cellulose→simple sugars				Snails; bacteria; fungi; malt.
21	Chlorophyllase	$CaCl_2$	Chlorophyll→chlorophyllide + phytol	5.9	1 mg/ml	25	Bacteria; leaves; stems.
22	Choline acetylase	CoA, ATP	Choline + acetyl CoA→acetylcholine	7			Brain; muscle; bacteria.
23	Chymotrypsin		Proteins→polypeptides + amino acids	7.6	5% casein	38	Pancreas.
24	Conjugase	Ca^{++}	Pteroylglutamate→pterine + glutamic acid	7-8		37	Pancreas tissues; yeasts; tubers.
25	Dehydrogenase, alcohol	DPN	Ethanol→acetaldehyde	7.8	0.03%	20	Liver; kidney; brain; blood; yeasts; hacteria; higher plants.
26	Dehydrogenase, glucose	DPN or TPN	β-Glucose→α-gluconic acid	7.4	0.2 M	38	Liver.
27	Dehydrogenase, glucose-6-phosphate	TPN	Glucose-6-phosphate→phosphogluconate	7.5	0.02 M	38	Blood; yeasts.
28	Dehydrogenase, glutamic	DPN or TPN	Glutamate→α-ketoglutarate + NH_3	8.2	0.0001 M	37	Liver; kidney: muscle; hrain.
29	Dehydrogenase, β-hydroxybutyric	DPN	L-β-Hydroxybutyrate→acetoacetate	7	0.05 M	38	Widespread.
30	Dehydrogenase, isocitric	DPN, TPN, Mg^{++}, Mn^{++}	D-Isocitrate→α-ketoglutarate + CO_2	7.0	0.0002M	25	Widespread.
31	Dehydrogenase, lactic	DPN	Lactate→pyruvate	9.3	0.02 M	20	Widespread.
32	Dehydrogenase, malic	DPN or TPN	L(-)Malate→oxalacetate	7.2	0.025 M	37	Brain; kidney; liver; muscle; widespread in plants.
33	Dehydrogenase, succinic	Cytochrome c (?)	Succinate→fumarate	7.4	0.01 M	37	Widespread.
34	Dehydrogenase, triosephosphate	DPN	D-Glyceraldehyde-3-phosphate→1, 3-diphosphoglycerate	8.6-9.0	0.0001 M	27	Widespread.
35	Dehydrogenase, yeast aldehyde	K^+, DPN+, cysteine	Acetaldehyde→CH_3COOH + DPNH + H^+				Yeast.
36	Desoxyribonuclease	Mg^{++}, Mn^{++}	Thymonucleic acid→nucleotides	6-7	0.5%	37	Intestinal mucosa; pancreas; seeds.
37	Emulsin β-glucosidase		Salicin→saligenin + β-D-glucose				Small intestine; bacteria; fungi; almonds; plants.
38	Enolase	Mg^{++}, Mn^{++}, Zn^{++}	2-Phosphoglycerate→(enol)phosphopyruvate	7	0.1 mg P/ml	20	Muscle; yeasts; leaves.
39	Esterase, acetylcholine		Acetylcholine→acetate + choline	7.4	3 mg/ml	37	Liver; pancreas; brain; blood; insects.
40	Esterase, acetylsalicylic acid		Acetylsalicylic acid→salicylic acid + acetic acid				Brain; kidney; liver.
41	Esterase, cholesterol		Cholesterol esters→cholesterol + acids	5.3 or 7			Liver; kidney; spleen; intestinal mucosa; blood; pancreas; hacteria.
42	Esterase, pectin		Pectin→pectate + methanol	6.2	1%	30	Leaves; fruits; bacteria.
43	Esterase, simple		Ethyl butyrate→ethnol + butyrate	8.0	Saturated	20	Widespread (animals); seeds; fungi.
44	Ficin	H_2S, HCN, cysteine	Proteins→amino acids and peptides(?)	5		35	Fig tree sap.
45	Fumarase		Fumaric acid→L(-)malic acid	6.6	0.025 M	40	Liver; muscle; bacteria; fungi; higher plants.
46	β-Galactosidase (lactase)		Lactose→galactose + glucose	5.6	2.5%	38	Bacteria; seeds.
47	α-Glucosidase (maltase)		Maltose→glucose	7.2	50 mg/ml	30	Intestinal mucosa; fungi; malt.
48	β-Glucosidase		β-Glucosides→glucose + aglycon	4.4-5.0	1 mg/ml	30	Intestinal mucosa; liver; kidney; bacteria; fungi; seeds.
49	β-Glucuronidase		β-Glucuronide→glucuronate + alcohol	4.5	0.001 M	38	Widespread (animals); bacteria; higher plants.

50	Glyoxalase	Glutathione	Methylglyoxal→lactate	7	1 mg/ml	25	Liver; kidney; muscle; blood; bacteria; fungi; seeds.
51	Guanase		Guanine→xanthine + NH_3	8.7	Saturated	40	Liver; pancreas; spleen; kidney; seeds.
52	Hexokinase	Mg^{++}, Mn^{++}	Hexose + ATP→hexosemonophosphate + ADP	7.5	0.001 M	30	Liver; muscle; kidney; brain; bacteria; yeasts; higher plants.
53	Histaminase		Histamine→aldehyde + H_2O_2 + NH_3	6.8-7.6	0.01 M	37	Widespread (animals); bacteria; fungi.
54	Histidase		Histidine→glutamate + formate + NH_3	8	0.01 M	38	Liver.
55	Hyaluronidase		Hyaluronate→acetylglucosamine + glycuronate	7.0	0.1%	37	Spleen; testes; insects; venoms; bacteria.
56	Invertase (sucrase, saccharase)		Sucrose→glucose + fructose	4.5	4 g/25 ml	20	Intestinal mucosa; invertebrates; fungi; bacteria; higher plants.
57	Lecithinase A		Lecithin→lysolecithin + fatty acid	7	Egg yolk	38	Liver; muscle; pancreas; venoms; mushrooms.
58	Lecithinase B		Lysolecithin→glycerylphosphorylcholine + fatty acid	4		41	Liver; spleen; pancreas; brain; fungi; seeds; rice bran.
59	Leucyl peptidase	Mg^{++}, Mn^{++}	Leucyl peptides→leucine + other amino acids	8-9	0.05 M	40	Intestinal mucosa; leaves; malt; bacteria; fungi.
60	Lipase	$CaCl_2$	Fats→glycerol + fatty acids	9	2.5 g/15 ml	30	Pancreas.
61	Lipase		Fats→glycerol + fatty acids	4.7-5.0			Bacteria; fungi; seeds.
62	Lipoxidase		Linoleic acid, etc.→oxidized fatty acids	6.5	0.02%	25	Intestinal mucosa; muscle; seeds.
63	Luciferase	Mg^{++}, ATP	Luciferin + O_2→oxidized luciferin + light	7.2	10^{-6} M	23	Insects; ostracods; bacteria; fungi.
64	Lysozyme		Bacterial cells→lysed bacterial cells	5.3		38	Nasal mucosa; latex of fig.
65	Oxidase, D-amino acid		D-Amino acids + O_2→α-keto acids + H_2O_2 + NH_3	8.6	0.01 M	38	Widespread (animals); fungi.
66	Oxidase, L-amino acid		L-Amino acids + O_2→α-keto acids + H_2O_2 + NH_3	8.8	0.015 M	38	Liver; kidney; venoms; fungi; bacteria.
67	Oxidase, ascorbic acid		L-Ascorbic acid + O_2→dehydroascorbate + H_2O	6.0	0.01 N	26	Widespread (plants).
68	Oxidase, cytochrome c		Ferro-cytochrome c + O_2→ferri-cytochrome c + H_2O	7.2	0.0001 M	37	Widespread (animals; plants).
69	Oxidase, glucose; (notatin)		β-Glucose + O_2→gluconate + H_2O_2	6.0	1%	39	Fungi.
70	Oxidase, xanthine		Xanthine or aldehyde→uric or other acids	7.5	0.003 M	20	Liver, milk.
71	Pepsin	HCN, H_2S, cysteine	Proteins, proteoses, etc.→amino acids	7.5	2%	30	Seeds, latex.
72	Pectinase		Pectin→galacturonide	4.0	0.5%	25	Bacteria; fungi.
73	Pepsin		Proteins→proteoses, peptones, amino acids	1.5-2.0	2%	20	Gastric mucosa.
74	Phosphoglucomutase	Co^{++}, Mg^{++}, Mn^{++}	Glucose-1-phosphate→glucose-6-phosphate	7.5-9.2	10^{-6} M	30	Widespread (animals; plants).
75	Phosphoglyceromutase		3-Phosphoglycerate→2-phosphoglycerate	7	10^{-5}M	24	Widespread (animals; plants).
76	Phosphomonoesterase I (alkaline phosphatase)	Mg^{++}	β-Glycerophosphate→H_3PO_4 + glycerol	9.2	0.02 M	37	Widespread (animals); bacteria; fungi. none in higher plants.
77	Phosphomonoesterase II (acid phosphatase)		β-Glycerophosphate→H_3PO_4 + glycerol	5-6	0.05 M	37	Prostate; spleen; liver; bacteria; fungi; seeds; tubers.
78	Phosphomonoesterase III		Monoesters of phosphate→H_3PO_4 + alcohols	3.4-4.2			Liver; spleen; fungi; seeds.
79	Phosphomonoesterase IV	Mg^{++}, Mn^{++}	α-Glycerophosphate→H_3PO_4 + glycerol	5.2-6.2			Blood; bacteria; yeasts.
80	Phosphorylase, amylo-	Starch or glycogen + phosphate	Dextrin + glucose-1-phosphate→starch or glycogen + H_3PO_4	6.8	0.001 M	30	Widespread (animals, plants).
81	Phytase	Mg^{++}	Phytate→inositol + phosphate	5.5-7.8	0.1%	37	Blood; intest. mucosa; fungi; seeds.
82	Pyrophosphatase I	Mg^{++}, Mn^{++}	Pyrophosphate→phosphate	7.2-7.8	0.001 M	38	Widespread (animals); fungi; seeds.
83	Pyruvic kinase	ADP, Mg^{++}, K^+	Phospho(enol)pyruvic acid→pyruvic acid + ATP				Yeasts; muscle; liver.
84	Q-enzyme		Amylose→amylopectin	7.0		21	Liver; muscle; seeds; tubers.
85	Reductase, cytochrome c	TPN	Ferri-cytochrom e c→ferro-cytochrome c	7.3	$2x10^{-5}$M	25	Liver; yeasts.
86	Rennin		Casein→paracasein	5.8	Raw milk	40	Calf stomach.
87	Ribonuclease		Ribonucleic acid→ribonucleotides	4-5	0.25 mg P/ml	25	Liver; spleen; pancreas; lungs; bacteria; higher plants.
88	Transaminase		Glutamate + oxalacetate→α-ketoglutarate + aspartate	7.5	0.02 M	40	Widespread (animals, plants).
89	Transphosphorylase, phosphocarboxyl-	Mg^{++}	1, 3-Diphosphoglycerate + ADP→3-phosphoglycerate + ATP	7.9	1 mg/ml	25	Muscle; yeasts.
90	Transphosphorylase, phospho(enol)-	Mg^{++}, K^+	Phosphoglyrurate + AMP→pyruvate + ATP		1.5 mM	38	Muscle; yeasts; higher plants.
91	Trypsin		Proteins, esp. denatured→polypeptides and amino acids	8-9	2.2%	25	Pancreatic juice.
92	Tyrosinase		Catechol, etc. + O_2→o-quinone, etc. + H_2O	5.5-7	2 mg/ml	25	Melanomas; skin; plants.
93	Urease		Urea→CO_2 + NH_3	7.0	1.5%	20	Blood; gastric mucosa; insects; bacteria; fungi; seeds.
94	Xylokinase	ATP	Xylose→xylose-5-PO_4 + ADP				Liver.

/1/ Abbreviations: ADP=adenosine diphosphate; AMP=adenylic acid, adenosine-monophosphate; ATP=adenosine triphosphate; CoA=coenzyme A; DPN=diphosphopyridine nucleotide, coenzyme I; DPNH=reduced DPN; TPN = triphosphopyridine nucleotide, coenzyme II. /2/ These conditions should be considered as indicative only, since the details vary widely with the method used and the source of the enzyme.

24. AMINO ACIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

	Amino Acids		Empirical Formula	Molecular Weight	Melting Point[1] °C	Solubility (g/100 ml)[2, 3]		Specific Rotation				pH at Isoelectric Point[3]
	Common Name	Synonyms				Water 25°C	Other Solvents	Solvent	g/100ml	Temp °C	$[\alpha]_D$	
1	L-Alanine	2-Aminopropanoic acid	$C_3H_7O_2N$	89.1	297	16.51	sl. s. al.; sl. eth.; acet.	HCl, 1.0N	5.79	15	+14.7	6.11(DL)
2	β-Alanine	3-Aminopropanoic acid	$C_3H_7O_2N$	89.1	196	v. s.	v. sl. s. al.; i. eth.			20		
3	α-Aminobutyric acid	2-Aminobutanoic acid	$C_4H_9O_2N$	103.12	285	28	0.18 al.; i. eth.	HCl, 20%		20	+14.1	5.98
4	L-Anserine	Methylcarnosine	$C_{10}H_{16}O_3N_4$	240.3				H_2O	5.0	20	+12.2	
5	L-Arginine	α-Amino-δ-guanidino-n-valeric acid	$C_6H_{14}O_2N_4$	174.21	238	v. s.	i. al., eth.	HCl, 6.0N	1.65	23	+26.9	10.76
6	L-Asparagine	α-Aminosuccinamic acid	$C_4H_8O_3N_2$	132.14	236	2.46	v. sl. s. al.; i. eth.; e. dil. NH_4OH	HCl, 3.4N	2.24	20	+34.3	5.41
7	L-Aspartic acid	α-Aminosuccinic acid	$C_4H_7O_4N$	133.11	269-71	0.50	v. sl. s. al.; i. eth.; e. dil. HCl	HCl, 6.0N	2.0	24	+24.6	2.98
8	L-Canaline	α-Amino-δ-(amino-oxyl)butyric acid	$C_4H_{10}O_3N_2$	134.14	214			H_2O	1.6	21	-8.1	
9	L-Canavanine	α-Amino-4-guanidinoxy-n-butyric acid	$C_5H_{12}O_3N_4$	176.2	184			H_2O	3.2	20	+7.9	7.93
10	L-Carnosine	β-Alanylhistidine	$C_9H_{14}O_3N_4$	226.3				H_2O	2.0	20	+20.5	
11	L-Citrulline	α-Amino-δ-carbamido-n-valeric acid	$C_6H_{13}O_3N_3$	175.2	222	v. sl. s.	i. al.	HCl, 1.0N	2.0	27	+24.3	
12	L-Cystathionine		$C_7H_{14}O_4N_2S$	222.3				HCl, 1.0N	1.0	22	+23.7	
13	Cysteic acid		$C_3H_7O_5NS$	169.15		s.						
14	L-Cysteine	2-Amino-3-mercapto-propanoic acid	$C_3H_7O_2NS$	121.15	175-78	v. s.	s. a., alk.	H_2O	2.0	21	-10.1	5.07
15	L-Cystine	3,3'-Dithiobis(2-amino-propanoic acid)	$C_6H_{12}O_4N_2S_2$	240.29	258-61	0.011	i. al., eth.; s. a.	HCl, 1.0N	1.0	24	-214.4	5.02
16	L-Dibromotyrosine	3, 5-Dibromotyrosine	$C_9H_9O_3NBr_2$	339.0	245[4]			HCl, dil.		20	+1.3	
17	L-Dihydroxyphenyl-alanine	α-Amino-β-3, 4-dihydroxyphenylpropionic acid; dopa[5]	$C_9H_{11}O_4N$	197.2	280	0.50	i. al., eth.; s. a., alk.	HCl, 4%	1.0	25	-12.0	
18	L-Diiodotyrosine	3, 5-Diiodotyrosine; iodogorgic acid	$C_9H_9O_3NI_2$	433.0	194	0.062		HCl, 1.1N	5.1	20	+2.9	4.29(DL)
19	L-Djenkolic acid	3, 3'-Methylenedithiobis(2-aminopropionic acid)	$C_7H_{14}O_4N_2S_2$	254.3	300-50	0.10		HCl, 1%	2.0	26	-44.5	
20	L-Ergothioneine	Betaine of thiolhistidine	$C_9H_{15}O_2N_3S$	228.29				H_2O	5.0	21	+116.0	
21	L-Ethionine		$C_6H_{13}O_2NS$	163.2		s.		HCl, 0.2N	0.8	25	+23.5	
22	L-Glutamic acid	α-Aminoglutaric acid	$C_5H_9O_4N$	147.13	247	0.86		HCl, 6.0N	1.0	22	+31.2	3.22(DL)
23	L-Glutamine	α-Aminoglutaramic acid	$C_5H_{10}O_3N_2$	146.15	185-6	4.25	v. sl. s. al.; i. eth.					5.65
24	Glycine	Aminoethanoic acid, glycocoll	$C_2H_5O_2N$	75.0	233	24.99	0.043 al. 90%				0	6.20
25	L-Histidine	α-Amino-β-imidazole-propionic acid	$C_6H_9O_2N_3$	155.1	277	4.19	v. sl. s. al.; [. eth.	H_2O	1.1	25	-39.0	7.64
26	L-Homocysteine		$C_4H_9O_2NS$	135.18		s.						
27	L-Homocystine		$C_8H_{16}O_4N_2S_2$	268.3		v. sl. s		HCl, 1.0N	1.0	26	+77	
28	L-Hydroxylysine	α, ε-Diamino-δ-hydroxy-n-hexanoic acid	$C_6H_{14}O_3N_2$	162.2	220			HCl, 1.0N	0.4	22	+7.5	
29	L-Hydroxyproline	4-Hydroxy-2-pyrrolidine-carboxylic acid	$C_5H_9O_3N$	131.1	238-41	36.11	v. sl. s. al.; i. eth.	H_2O	1.0	22	-75.2	5.82
30	L-Isoleucine	2-Amino-3-methyl-pentanoic acid	$C_6H_{13}O_2N$	131.17	283-4	4.12	0.09 sl. s. al. eth. s. hot acet. a.	HCl, 1.1N	5.1	20	+40.6	6.04(DL)
31	L-Lanthionine	β-Amino-β-carboxy-ethyl sulfide	$C_6H_{12}O_4N_2S$	208.3							(DL)	
32	L-Leucine	2-Amino-4-methyl-pentanoic acid	$C_6H_{13}O_2N$	131.17	295	2.19	0.022 al.; i. eth.; s. ac. ac.	HCl, 6.0N	2.0	26	+15.1	6.04(DL)
33	L-Lysine	2, 6-Diaminohexanoic acid	$C_6H_{14}O_2N_2$	146.19	224	v. s.	v. sl. s. al.; i. eth.	HCl, 6.0N	2.0	23	+25.9	9.47
34	L-Methionine	α-Amino-γ-methylthio-n-butyric acid	$C_5H_{11}O_2NS$	149.21	283	5.75	i. eth.	HCl, 0.2N	0.8	25	+21.2	5.74(DL)
35	L-Norleucine	α-Aminocaproic acid	$C_6H_{13}O_2N$	131.17	301	1.149(DL)	0.017(DL) sl.	HCl, 6.0N	4.3	20	+21.3	6.08(DL)
36	L-Norvaline	2-Aminopentanoic acid	$C_5H_{11}O_2N$	117.1	291-2	10.7[6]	sl. s. al.; i. eth.	HCl, 20%	5	20	+22.8	
37	Octopine		$C_9H_{18}O_4N_4$	246.27								
38	L-Ornithine	2, 5-Diaminopentanoic acid	$C_5H_{12}O_2N_2$	132.2	225	v. deliq.	v. s. al.; sl. s. eth.	H_2O	4.0	27	+16.5[7]	
39	L-Phenylalanine	α-Amino-β-phenyl-propionic acid	$C_9H_{11}O_2N$	165.2	283	2.96	sl. s. al.; i. eth.	H_2O	1.9	20	-35.1	5.91(DL)
40	L-Proline	2-Pyrrolidinecarboxylic acid	$C_5H_9O_2N$	115.1	220-2	162.3	1.55 al.; i. eth.	HCl, 0.5N	0.6	20	-52.6	6.3
41	Sarcosine	Methyl glycine	$C_3H_7O_2N$	89.1	210	v. s.	sl. s. al.; i. eth.				0	6.00
42	L-Serine	α-Amino-β-hydroxy-propionic acid	$C_3H_7O_3N$	105.1	228	5.023(DL)	i. al., eth.	HCl, 1.0N	9.3	25	+14.5	5.68(DL)
43	L-Thiolhistidine	α-Amino-β-2-thioimidazolepropionic acid	$C_6H_9O_2N_3S$	187.2				HCl, 1.0N	1.0	25	-9.5	
44	L-Threonine	α-Amino-β-hydroxy-n-butyric acid	$C_4H_9O_3N$	119.12	229-30	20.1(DL)	i. al., eth.	H_2O	1.0	26	-28.4	5.59
45	L-Thyroxine	α-Amino-β-[3, 5-diiodo-4-(3', 5'-diiodo-4'-hydroxyphenoxy)phenyl]-propionic acid	$C_{15}H_{11}O_4NI_4$	776.9	235-6	0.001	i. al., eth.	NaOH, 0.1N	3		-4.4	
46	L-Tryptophan	α-Amino-β-indole-propionic acid	$C_{11}H_{12}O_2N_2$	204.2	289	1.14	sl. s. al.; i. eth.	H_2O	1.0	20	-31.5	5.88
47	L-Tyrosine	α-Amino-β-(p-hydroxy-phenyl)propionic acid	$C_9H_{11}O_3N$	181.2	295	0.045	0.01 al., i. eth., acet. a. alk.	HCl, 6.3N	4.4	20	-8.6	5.63
48	L-Valine	α-Aminoisovaleric acid	$C_5H_{11}O_2N$	117.15	293	8.85	0.019 al. (DL)	HCl, 6.0N	3.4	20	+28.8	6.00(DL)

/1/ Most amino acids decompose when they melt. /2/ s. =acid; acet. =acetone; acet. a. =acetic acid; al. =alcohol; alk. =alkali; deliq. =deliquescent; dil. =dilute; eth. =ether; i. =insoluble; s. =soluble; sl. =slightly; v. =very. /3/ DL=racemic mixture. /4/ Dihydrate. /5/ 3, 4-Dihydroxyphenylalanine. /6/ At 50°C. /7/ Dihydrochloride.

25. BIOLOGICAL SUBSTANCES: MOLECULAR SIZE AS DETERMINED BY IONIZING RADIATION

Values are "molecular weights" obtained at room temperature, except where noted, but do not have the accuracy and reliability of certain physical constants. Ionising radiation can be used to determine approximate shape and structure of molecules as well as molecular weights.

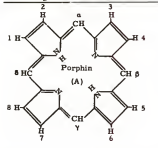
	Material	Reported Molecular Size	Molecular Weight Determined by:[1] Electrons	Heavy Particles	Remarks
1	ACTH	4566		2400	Entire molecule not needed for activity.
2	α-Amylase	100,000-200,000	145,000		Requires 3 simultaneous ionizations for inactivation.
3	Catalase	250,000		58,000 at 90°K 110,000 at 300°K 250,000 at 350°K 500,000 at 385°K	1/4, 1/2, 1, and 2 molecules (?).
4	Chymotrypsin	23,000	50,000	48,000 28,000	Casein digestion assay; polymer (?). Milk clotting assay.
5	Colicine K		60,000-90,000		
6	Cytochrome oxidase	75,000/mole hemin	150,000		Requires 3 simultaneous ionizations for inactivation.
7	Dehydrogenase, succinic	110,000-140,000	310,000		Requires 3 simultaneous ionizations for inactivation.
8	DNA (absorption spectrum unit)	1300 and 5500 found as digestion products.	2100	500 A^2	Breakup of larger DNA units increases absorption coefficient before digestion with DNA-ase.
9			700,000(X rays)		
10	DNA (pneumococcus transforming principle)		At least 2 components, one $<10^6$, another $>2x10^6$.		Biologically active unit.
11			(5-7)x10^6	Non-spherical	
12	DNA-ase	63,000	62,000	62,000	
13	Dysentery toxin		11,000	11,000	Toxic unit.
14	Gramicidin	8700	6400	6000	
15	Hemocyanin	6.7-8 x 10^6		6,700,000	
16	Hemoglobin, pH5	67,000	46,000	46,000	
17	Hemoglobin, pH7	67,000	66,000		Requires 3 simultaneous ionizations for inactivation; effect on solubility of molecule.
18	Hyaluronidase (HUA-ase)	65,000; 11,000 purified	75,000	75,000 (globular)	
19	Hyaluronic acid (HUA)		100,000	100,000 (long, thin)	Same at 90°K.
20	Hyaluronic acid-hyaluronidase complex			175,000	Assayed for enzyme activity.
21	Insulin	n x 5000	23,000	23,000 (spherical)	Assayed for biological activity.
22	Invertase	120,000	120,000	123,000	Varies with temperature.
23	Mucoprotein, sheep	87,000		82,000	Assumed long and thin.
24	Myosin	840,000	470,000		
25	Oxytocin	1007	1800		Dimer (?).
26	Penicillin	356		550	Cluster size comparable to molecular size.
27	Pepsin	36,000-39,000		39,000	
28	Peptides, di- and tri-	130-250		400-900	Assayed chromatographically; cluster size comparable to molecular size.
29	Ribonuclease	13,000	21,000 30,000 (X rays)		
30	Serum albumin, bovine, bulk	69,000	83,000		Requires 3 simultaneous ionizations for inactivation; effect on solubility of molecule.
31	Serum albumin, bovine, monolayer	69,000		7000	Serological unit.
32	Trypsin	15,000-24,000	34,000	31,000	Dimer (?); independent of substrate used for assay.
33	Trypsin (soybean) inhibitor	24,000 9,000	12,000	12,000	
34	Trypsin - STI complex	41,000 30,000	30,000	30,000	
35	Urease	100,000[2]	87,000	87,000	

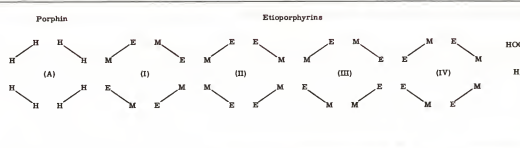
/1/ For general description of method used to obtain molecular sizes from radiation data, and for references to original literature, see Pollard, E. C., et al, Progress in Biophysics 5:72, 1955. /2/ Recent value; old value 480,000.

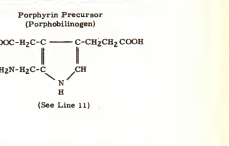
Part I: PORPHYRINS

These pigments are derived from porphin (A) by substitution of the nuclear hydrogen atoms. There are four stereoisomers called "etioporphyrins" (I, II, III, IV) which are used as the basis for classifying naturally occurring porphyrins. The natural porphyrins correspond to etioporphyrins I and III; chlorophylle and hemoglobins are of type III only; free porphyrins are predominately of type III; small quantities of type I in physiological condition, great quantities in some pathological states.

A = (-CH_2-COOH); B = (-CHO); D = (-CO-CH_3); E = (-CH_2CH_3); H = hydrogen; M = (-CH_3); P = (-CH_2-CH_2-COOH); V = (-CH:CH_2); X = (-CO-CH_2-)[1]; Y = [-CH(OH)-CH_3] ; Z = [-CO-CH(COO·CH_3)-][1]







	Porphyrin	Substituente in Positione[2] 1	2	3	4	5	6	7	8	Physical and Chemical Properties[3,4]	Spectral Characteristics λmaximum in mμ[5] Form[6]	Solvent[4]	I	II	III	IV	Soret	Occurrence in Nature
1	Chlorocruroporphyrin	M	B	M	V	M	P	P	M									Fe complex prosthetic group of chlorocruorin of Sabellid worms.
2	Coproporphyrin I ($C_{36}H_{38}O_8N_4$)	M	P	M	P	M	P	M	P	MP me.est. = 248-258°C; HCl No. me.est. 1.5; s.eth.-ac. a.	Free, or me.est.	Neutral (eth.-ac.e.)	623.5	568	528.5	495	405	Free form in feces, urine, erythrocytes, bile, yeast, bacteria. Widespread in traces in animals, plants, microorganisms. Increased pethological in porphyrinurias and porphyrias.
3	Coproporphyrin III ($C_{36}H_{38}O_8N_4$)	M	P	M	P	M	P	P	M	MP me.est. = 157°C, remells at 172°C; HCl No. me. est. = 1.5; s. eth.-ac. e.								
4	Deuteroporphyrin IX ($C_{32}H_{32}O_4N_4$)	M	H	M	H	M	P	P	M	MP me.est. = 218-224°C; HCl No. me. est. 2,0; s. chl.			621.5	566	526	494		Free form in human feces.
5	Mesoporphyrin ($C_{34}H_{38}O_4N_4$)	M	E	M	E	M	P	P	M	MP me.est. = 216°C; HCl No. me. eet. 2.5.		Neutral (eth. -ac. a) Pyridine	623.5	567.5	528.5	494.5	391	Free form in feces, ambergris.
6	Oxophesoporphyrin-a_5	M	D	M	E	M	Z	P	M									Mg complex of 3, 4, 7, 8-tetrahydroporphyrin, esterified with phytol (in side chain 7); bacteriochlorophyll. Another porphyrin with an acetyl side chain is probably the prosthetic group of milk peroxidase.
7	Pheoporphyrin-a_5	M	E	M	E	M	Z	P	M									
8	Pheoporphyrin-b_5	M	E	B	E	M	Z	P	M									
9	Vinylpheoporphyrin-a_5	M	E	M	V	M	Z	P	M									Mg complex in chlorella mutant esterified with phytol in 7=protochlorophyll. Mg complex of 7,8-dihydroporphyrin esterified with phytol in 7=chlorophyll a.
10	Vinylpheoporphyrin-b_5	M	E	B	V	M	Z	P	M									Mg complex of 7, 8-dihydroporphyrin esterified with phytol in 7=chlorophyll b.
11	Phylloerythrin IX ($C_{33}H_{34}O_3N_4$)	M	E	M	E	M	X	P	M	MP me. eet. = 213°C; HCl No. free porphyrin. 7-9.	Free	Acetone	636.8	589.4	560.8	521.8		Free form in feces and bile of ruminants.
12	Porphobilinogen ($C_{10}H_{14}O_4N_2$) (monopyrrole)	A	P	-	-	-	-	-	-	MP hydrochloride = 165-170°C; i.e.w., org. solvente.								Obligatory precursor for biosynthesis of porphyrins and heme; in urine in hepatic porphyria, lead and sedormid poisoning; gives red compound with Ehrlich's reagent which is insoluble in $CHCl_3$.
13	Porphyria (cytoporphyrin)	Two or three M, 2 P, 1 B, one long elkyl, probably IV.																Fe complex prosthetic group of cytochrome oxidase (cytochrome-a_3) and cytochromes c, c_1.

14	Protoporphyrin IX ($C_{34}H_{34}O_4N_4$)	M	V	M	V	M	P	P	M	MP me. est. = 225-230°C; HCl No. me. est. 5.5; s. eth.-ac.a.	Free, or me. est.	Neutral (eth.-ac.a) Pyridine	623,5	576	537	502	395	Free form in bone marrow, erythrocytes, feces, chloroma, Harderian glands (rodents), bird egg shells, earthworm. Fe complex (heme) prosthetic group of hemoglobins, myoglobins, catalase, peroxidase (horseradish), cytochrome-b, cytochrome-c (modified). Mg complex in chlorella mutant.
15	Uroporphyrin I ($C_{40}H_{38}O_{16}N_4$)	A	P	A	P	A	P	A	P	MP me. est. =293°C; HCl No. 7; i.eth.-ac.a; extr. from aq. sol. (pH 3.0-3.2) with eth. acetate.								Very small amounts in normal human urine, larger amounts in some forms of porphyria and lead poisoning. Also present in mollusk shells and some plants. Normal in urine of Sciurus niger. Porphyrins with 5-7 carboxyl groups also occur.
16	Uroporphyrin III ($C_{40}H_{38}O_{16}N_4$)	A	P	A	P	A	P	A	P	MP me. est. = 264°C; other properties same as Uroporphyrin I.		Chloroform	626	570,5	536	501	408	Very small amounts in urine, larger amounts in some forms of porphyria and sedormid poisoning. Cu complex: turacin in turaco feathers may serve as source of uroporphyrin III.

/1/ Substituent groups X and Z constitute bridges between C_6 and C_7. /2/ Letters in the columns refer to substituents (abbreviated as per code) appearing in the position indicated by column number (numbers correspond to those in reference structural formula). /3 All porphyrins show a strongly red fluorescence in Wood's light both in acid and alkaline solutions and in many neutral solutions. /4/ Abbreviations: ac.a. = acetic acid; aq. = aqueous; c. = cold; est. = ester; eth. = ether; i = insoluble; me. = methyl; MP = melting point; s. = soluble. /5/ λ-maximum in $m\mu$ = wave length of maximum absorption. /6/ Free porphyrin and its ester give the same bands in the same solvents.

Part II: IRON-PORPHYRIN PIGMENTS

	Substance	General Nature	Physical and Chemical Properties[1]	Spectral Characteristics λ-maximum in $m\mu$[2]	Remarks
				Heme Compounds	
1	Hematin (hydroxy-hemin) ($C_{34}H_{33}O_4N_4Fe$)	Fe^{+++} complex of protoporphyrin; moderately stable.	s. alk.	Alcohol HCl 400(131-151) $E^{1\%}_{1cm}$ 1960-2260 Acetic acid 630-635 540 510 400 (Soret) 10% NaOH 580(10.5) Alcoholic $NaHCO_3$ 590 402.5(79.5) $E^{1\%}_{1cm}$ 1190 Ether 650 Reducing agent (Stoke's) produces hemochromogen bands.	Produced by atmospheric oxidation of hems; present in serum in hemolytic and pernicious anemia, malaria, congenital porphyria, certain poisonings, septicemia, severe liver damage; bound to serum albumin as methemalbumin; occasionally present in bile, feces, urine.
2	Heme (protoheme IX) ($C_{34}H_{32}O_4N_4Fe$)	Fe^{++} complex of protoporphyrin; extremely unstable, easily oxidized to hematin.	Fe removed by dilute HCl in glac. ac. a.	Phosphate buffer, pH 7 550 575 415 (Soret) $E^{1\%}_{1cm}$ 895	Occurs as prosthetic group of hemoglobin; combines with many N-containing bases to form hemochromes.
3	Hemin (chlorohemin) ($C_{34}H_{32}O_4N_4FeCl$)	Crystalline chloride of hematin; stable.	Br. or blk. cryst.; s. dil. alk., strong organic bases; i.a.	0.1N KOH 645.2 591 539.7 (Best identified by conversion to hemochromogen)	Not found in nature. Crystals sinter at 240°C, melt at 300°C. Converted to hemochromogen by $Na_2S_2O_4$ + pyridine.
4	Methemalbumin (ferrihemalbumin)	Compound of hematin and serum albumin. Iron is in Fe^{+++} state.	Easily soluble in water as serum albumin.	623 540 500 Reduction to Fe^{++} analogue 570 530 (ferrohemalbumin) (Spectrum unstable in presence of dithionite (of Hb))	Found in plasma in blackwater fever, severe anemias, severe liver damage, blood extravasates, etc.
5	Pyridine hemochromogen	Compound of heme + pyridine, 2 molecules of which are coordinately linked with the Fe atom. Term "hemochromogen" or "hemochrome" also used generically for coordination compounds of hems with nitrogenous bases.		558(31-35.3) 525(16.2)	Term "hemochromogen" also used generically for nitrogenous compounds combined with heme; all have similar spectra.
6	Spirographishemin (chlorocruroheminic) ($C_{33}H_{32}O_6N_4FeCl$)	Hemin of chlorocruroporphyrin.	Same as hemin (above).	CO compound of chlorocruroheme. 410(Soret)	Prosthetic group in chlorocruorins. No function per se, only as part of chlorocruorins.
				Hemoglobin Compounds	
7	Carboxyhemoglobin	Compound of 4 molecules CO per 4 Fe of Hb; iron in Fe^{++} state.	MW = 66,700. Solubility similar to that of Hb.	568-572(13.7-15) 538-540(14.1-15.3) 418(154)	Diluted solutions are pink (cf HbO_2); also distinguished from HbO_2 by stability of spectrum in presence of reducing agents.
8	Hemoglobin (Hb)	Four heme molecules + globin; iron in Fe^{++} state.	MW = 66,700, easily soluble in water, varying with pH and salt concentration; red-purple color.	Main band at 560 Slight variation according to species of origin. 555(12.9-13.6) 430[Soret] (118-134)	O_2 carrier in red corpuscles of all vertebrates. Combines reversibly with O_2 to form oxyhemoglobin, and with CO to form carboxyhemoglobin (affinity for CO 400 x that for O_2). Several varieties of human Hb known: A, F, S, C, D, E, G.

/1/ Abbreviations: s. = acid; ac.a. = acetic acid; alk. = alkali(ne); blk. = black; br. = brown; cryst. = crystal; dil. = dilute; i. = insoluble; MW = molecular weight; s. = soluble. /2/ λ-maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E^{1\%}_{1cm}$, i.e., extinction coefficients of millimolar solutions of 1cm thickness; $E^{1\%}_{1cm}$ = extinction coefficients of 1% solutions of 1cm thickness.

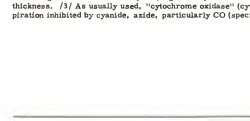
Part II: IRON PORPHYRIN PIGMENTS (Concluded)

	Substance	General Nature	Physical and Chemical Properties[1]	Spectral Characteristics maximum in $m\mu$[2]	Remarks
9	Methemoglobin (Met Hb)	Like Hb, except iron is in Fe^{+++} state.	MW = 66,700; solubility differs from Hb, depending on pH.	Acid solution 630(3.7–3.8) 500(9.5) 405–407(Soret)(134–154) Alk. solution 577(9.5) 540(9.7) 411 (Soret) (71–90) Addition of Stoke's reagent produces spectrum of Hb (cf hematin)	Small amounts normally present in red blood cells. Larger amounts formed by oxidation (K ferricyanide, nitrites, chlorates, phenacetin, sulfonamides).
10	Myohemoglobin (Mb or MHb)	Heme + globin (different from globin in Hb), Fe^{++} readily oxidized to Fe^{+++} (Met Hb).	MW = 16,900–19,000. More soluble than Hb in sat. $(NH_4)_2SO_4$;more alkali resistant than Hb.	Aqueous solution 555 435 Myooxyhemoglobin is differentiated from oxyhemoglobin by the position of its α-band at 582 mμ.	In all muscles of higher vertebrates, terrestrial and aquatic; also in nematodes, molluscs. Main function is to store O in muscles (completely saturated with O_2 at low pressures).
11	Oxyhemoglobin (HbO_2)	Compound of Hb with 4 equivalents of oxygen, available physiologically; iron in Fe^{++} state.	MW = 66, 700. Solubility similar to Hb. Bright red color.	577(15.1–16.2) 540–542(14.2–15.3) 412–415 (Soret)(125–128.3)	Present in fresh blood of all vertebrates; diluted solutions are yellow (cf HbCO); reduced to Hb by dithionite with color changes from rose to violet-red.
12	Sulfhemoglobin (HbS)	From treatment of Hb with H_2S+ O_2 (chemical structure not definitely ascertained); not more than 10% HbS formed.	MW = 66,700. Solubility similar to that of Hb.	617 623 (11). Band stable in presence of dithionite (cf methemalbumin) and in presence of NaCN/Na_2CO_3. 620 (CO) 612 618 (16)*	No physiological function; pathological product; occurs in erythrocytes after administration of sulfur, sulfonamides, trinitrotoluene, aromatic amines, and in certain septicemias.
13	Chlorocruorin (Ch)	Globin + chlorocruroheme (molecule contains many such units).	MW about 3 x 10^6. Solubility similar to Hb.	Reduced form 574 (broad band) Oxidized form 604 560 CO compound 600 507	Found in several species of annelids (Polychaeta), *e.g.*, Spirographis, a marine worm.
14	Choleglobin	Native globin + prosthetic group (composition not clear). Formed by coupled oxidation of Hb with ascorbic acid.	Solubility similar to Hb. Degradation product yields biliverdin.	Fe^{++} compound (aqueous solution) 629 Fe^{+++} compound (aqueous solution) 674 Fe^{++}CO compound (aqueous solution) 628	Formed in blood in certain septicemias and poisonings (phenylhydrazine). Is normal Hb degradation product intermediary in bile pigment formation.
15	Erythrocruorins (invertebrate hemoglobins)	Protoheme + globins (different from vertebrate globins).	Solubility similar to Hb. Combines similarly to Hb with O_2 and CO_2.	Absorption maxima similar to Hb with minor differences according to species.	
			Hematin Enzymes		
16	Catalase	Hematin-containing enzyme; catalyzes decomposition of H_2O_2, and peroxidation of certain substrates by H_2O_2.	MW about 220,000. 4 hematins per molecule. Iron is Fe^{+++}, not reducible by $Na_2S_2O_4$.	629–622(10.8) 544–536 506.5–500 409–400[145) 280–266	Present in aerobic cells, highly concentrated in a few animal tissues (liver, red cells); absent only in strict anaerobes, and a few facultative anaerobes. Catalytic activity inhibited by cyanide, H_2S, hydroxylamine, azide, o-aminophenol, 2,4-dichlorophenol and other compounds.
17	Cytochromes a, a_3; a_1, a_2[3]	Heme of porphyrin a (Part I, No. 13) is prosthetic group of a, a_3 and probably a_1; heme of chlorin is prosthetic group of a_2.	MW unknown. a_1 and a bound in mitochondria, probably as lipoprotein complex. Soluble only as complex with cholate and similar compounds.	Reduced a_3 + a 605–600 (due to a_3 and a) 445 (due mainly to a_3) a_3CO 590–630 (a does not react with CO) Reduced a_1 590 435–440 Reduced a_2 635–630 (Soret band weak or absent)	Cytochromes a_3, probably also a_1 and a_2, react directly with oxygen (oxidases; cytochrome-a only electron carrier); a_3 + a widespread in animals, plants, and some bacteria; a_1 and a_2 in other bacteria.[4]
18	Cytochrome-c, c_1[3]	Prosthetic group based on hematoporphyrin modified by firm sulfur linkages to cysteine groups of protein.	MW = 13,500–16,000. Soluble, very stable protein; non-auto oxidizable, does not react with CO. E_0' (pH 7.0, 37°C = 0.25 volts.	Cytochrome Fe^{++} 550(26–28) 522(15.5–16.9) 415[(143) 345 316 Fe^{+++} 565 (indistinct) 530(9.4–9.7) 407(112) 346	Occurs in all animal and plant cells, and in cells of most microorganisms. Specific electron carrier reacting with cytochrome-a.
19	Cytochromes b	Prosthetic group protoheme; for b_2 = protoheme + flavin.	Only b_2 (lactic dehydrogenase of yeast) prepared as soluble cryst. enzyme; b in mitochondria. All members rendered autooxidizable,do not react with CO. E_0' of b (pH 7.0, 37°C) = 0 (approx.)	Reduced band in region 565–555 Soret band about 430	Essential electron carriers below cytochrome-c in the respiratory chain. Occur in all living cells of animals, plants and microorganisms, except strict anerobes.

20	Peroxidases	Prosthetic groups (1) for horseradish and cytochrome-c peroxidases = protohemin; (2) for lactic peroxidase = hemin (of a different porphyrin); (3) for myeloperoxidase = group similar to that of cholegloblin.	MW = 44,100, with one hematin group. Soluble enzyme. Iron Fe^{+++} reduced by dithionite.	In neutral solution Dithionite	645(12)	583	548 498 558 594 (weak)		Peroxidases occur in plants and animals; biological functions still inadequately known. Detection by treatment of material with H_2O_2 + benzidine; green color develops.

/1/ Abbreviations: a. = acid; ac. a. = acetic acid; alk. = alkali(ne); blk. = black; br. = brown; cryst. = crystal; dil. = dilute; i. = insoluble; MW = molecular weight; s. = soluble. /2/ λ-maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E\,\frac{1\%}{1cm}$ i.e., extinction coefficients of millimolar solutions of 1 cm thickness; $E\,\frac{1\%}{1cm}$ = extinction coefficients of 1% solutions of 1cm thickness. /3/ As usually used, "cytochrome oxidase" (cytochrome-c oxidase) equals a_3 + a, strictly only a_3 (atmungsferment); cytochromes a_1 and a_2 are also oxidases in microorganisms. /4/ Respiration inhibited by cyanide, azide, particularly CO (specific light reversion of inhibition).

Part III: THE BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS



(A)

These are derivatives of the tetrapyrrolic structure (A) formed by varying degrees of oxidation, and substitution of the nuclear H atoms 1, 2, 3, 4, 5, 6, 7, 8. While formula (A) describes the bilirubinoids as linear tetrapyrrolic chains with terminal hydroxyl groups, their structure is more correctly described as that of a tetrapyrrolic ring closed by a hydrogen bond between oxygen atoms ($_{19}$>CO-HOC$<_{8}$). All natural members are derived from Fischer's protoporphyrin IX by fission at the α-methene link. They are therefore known as Bilirubinoids IX-α. The main characteristics are as follows:

(Gm) Gmelin reaction: given by bilirubins; the later stages also by biliverdins and bilipurpurins.
(Di) Diazo reaction: depending on the splitting of the molecule at a central $-CH_2-$ group.
(Eh) Ehrlich reaction: characteristic of bilanes.
(Pe) Pentdyopent reaction: given by most bile pigments, hematin compounds and dipyrryl methenes.
(Sc) Schlesinger reaction: given by dipyrryl mathenes.
(Fe) Ferric chloride reaction: given by all except trienes and more highly oxidized pigments, and except tetrahydromesobilane and -bilene.

Substituent groups: E = $(-CH_2CH_3)$; H, H_2 = hydrogen; M = $(-CH_3)$; OH = hydroxyl; P = $(-CH_2CH_2COOH)$; V = $(-CH{=}CH_2)$. + = positive reaction; (+) = non-characteristic reaction; - = negative reaction.

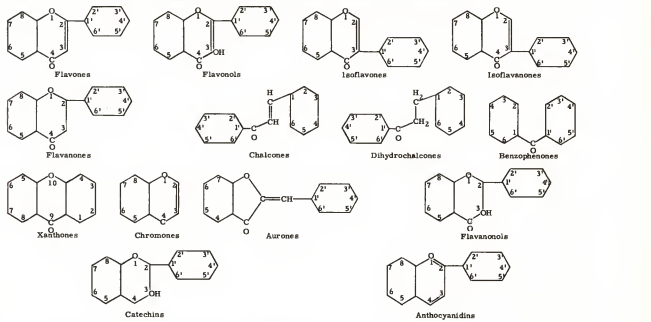
	Substance	Substituents in Positions 1	2	3	4	5	6	7	8	Physical and Chemical Properties[1]	Spectral Characteristics λmaximum in $m\mu$[2]		Reactions Gm	Di	Eh	Pe	Sc	Fe	Remarks
		1'	2'	3'	4'	5'	6'	7'	8'										
										Bilanes and Hydrobilanes									
1	Mesobilane (mesobilirubinogen, urobilinogen IX-α) $(C_{33}H_{44}O_6N_4)$	M	E	M	P	P	M	M	E	Color: l. cryst.; MP = 199°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.			-	-	+	+	-	+	Hemoglobin degradation product. In feces; a little in normal, more in pathological urine and bile. Distinguish from 2 (below) by Fe reaction or by violet pigment (bands at 665, 600, 510 $m\mu$) on warming with NaOH-$CuSO_4$.
		H	H_2	H	H	H_2	H	H_2	OH										
										Red pigment (s. chl.) on treatment with Ehrlich reagent: about 560 $m\mu$ (64.5).									
2	Tetrahydromesobilane (stercobilinogen) $(C_{33}H_{42}O_6N_4)$	M	E	M	P	P	M	M	E	Color: l., non-cryst.; MP = 125-150°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.			-	+	+	+	-	+	Main excretory product of hemoglobin in most vertebrates. Distinguish from 1 (above) by negative Fe reaction, or NaOH-$CuSO_4$ reaction (only one band at 530-500 $m\mu$.
		H	H_2	H	H	H_2	H	H_2	OH										
		+4H																	
										Bilenes and Hydrobilenes									
3	Mesobilene (urobilin IX-α) $(C_{33}H_{42}O_6N_4)$	M	E	M	P	P	M	M	E	Reddish yel. col.; MP free substance 190°C, ·HCl = 199°C; s. al., am. al., chl., dil. alk.; sl.s.eth.; i.w.	Dioxane	452(25,1)	330(3,6)	-	-	-	+	+	+	Oxidation product of 1(above). Distinguish from 4(below)by positive Fe and Pe reactions, optical inactivity and band position in alcohol HCl in reversion spectroscops.
		H	H_2		H	H	H_2	H	OH		Alcohol HCl	490(50,1)	375(7.4)						
											Zn complex in me. al.		509.5						
4	Tetrahydromesobilene (stercorubilin) $(C_{33}H_{46}O_6N_4)$	M	E	M	P	P	M	M	E	Reddish yel. col.; MP free substance 236°C, ·HCl = 165°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.	Dioxane	456(33.0)		-	-	-	+	+	-
		H	H_2		H	H	H_2	H	OH		Alcohol HCl	488(55)	372(8,5)						Oxidation product of 2 (above). Distinguish from 3 (above) by stability in presence of $FeCl_3$, negative Fe reaction and optical activity (levorotatory).
		+4H									E band (Na salt in H_2SO_4)	530							
											Zn complex in alcohol	506.5							
											Cu complex in alcohol	515							
											$[\alpha]_D$ free	320							
											$[\alpha]_D$ ·HCl	3800							

/1/ Abbreviations: ac.a. = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; col. = color; colorl. = colorless; cryst. = crystal(line); dil. = dilute; dimath. = dimathyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; purp. = purple; pyr. = pyridine; sl. = slightly; s. = soluble; vit. = violet; w. = water; yel. = yellow. /2/ λ-maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E\,\frac{1\%}{1cm}$, i.e., extinction coefficients of millimolar solution of 1cm thickness.

Substance	Substituents in Positions 1 / 2 / 3 / 4 / 5 / 6 / 7 / 8	Physical and Chemical Properties[1]	Spectral Characteristics λmaximum in mμ[2]		Reactions Gmelin Diazo	Remarks
Biladienes						
5 Bilirubin ($C_{33}H_{36}O_6N_4$)	M / V / M / P / P / M / M / V H / H / H / H_2 / H / H / OH	Or. col.; MP dimath. sstar 198-200°C; sol. hot pyr., hot chl., CCl_4, dil. alk.; sl. s. ncat., sth. ac.; i.w., al., eth.	Chloroform NaOH	450(56) 420	+ / + / - / + / - / +	Breakdown product of hams compounds in bila, fecas of newborn, hemorrhagic infarcts (hamatoidin), gallstonas. Present in serum, urina, tiasmas during jaundice. Reduction with Na/Hg gives masobilina. Sc reaction with iodina: 635 mμ band of bilipurpurin.
6 Masobilierythrin (masobilirhodin) ($C_{33}H_{40}O_8N_4$)	M / E / M / P / P / M / M / E H / H_2 / H / H / OH / H_2 / O M / E / M / P / P / M / M / E H / H_2 / H / H / H / OH	Red col.; a. bz., chl.; sl. s. eth.; i.w.	HCl/chloroform HCl, 5% Zn complex in alcohol	605(weak) 557(weak) 497 560 495 630(weak) 509	- / - / - / + / + / + grn.-yel. fluorescence	Proathatic group of phycoerythrin of rad and soma blue algas; afficiant photosensaitizer in algal photosynthesis. Related compound in Aplysia.
7 Masobilirubin ($C_{33}H_{40}O_8N_4$)	M / E / M / P / P / M / M / E H / H / H_2 / H / H / OH	Yel. or or.col.; MP free substances = 315°C, dimath. sstar = 190°C; s. pyr., chl., dil. alk.; sl. s. eth. sc., eth.; i.w.	Chloroform	425(61.4)	+ / + / - / + / - / +	Possibly prasent in small intestina. Reduction with Na/Hg gives mesobilana. Sc reaction with iodina: 625 mμ band of masobilipurpurin.
8 Masobiliviolin ($C_{33}H_{40}O_6N_4$)	M / E / M / P / P / M / M / E H / H / H / H / H_2 / H / OH	Vit. col.; MP·HCl = 165°C, s. bz., chl.; sl. s. sth.; i.w.	Chloroform Aqueous HCl Zn complex in alcohol	570-575 598 625-629 575(weak)	- / - / - / + / + / + red fluorescance	In human facas, probably derived from masobilina. Prosthatic group of phycocyanins (chromoprotains of rad and blua algas) which act as afficient photosensitizars in algal photosynthasis. Ralated compound in Aplysia.
Bilatrienes						
9 Biliverdin[3] ($C_{33}H_{34}O_8N_4$)	M / V / M / P / P / M / M / V H / H / H / H / H / OH	Blua-grn.col.; MP dimeth. sst. = 215°C; s. hot meth. al., hot glac. ac.a., dil. alk.; sl. s. sth., chl., dil. HCl; i.w.	Methyl alcohol 5% HCl/methyl alcohol Aqueous HCl/alcohol	640(10.4) 392(25) 680(28) 377(48) λmax 675 λmin 500	+ / - / - / + / - / -	In gr. bila of soma animals, egg shalla of many birds (oocyan), placanta of soma mammals (uterovardin), hamatomas. Green stage of Gmalin raaction. Bilvardin-iron prasent as prosthatic group of (inactive) liver catalasa. Sc reaction with iodina asma as for bilirubin.
10 Glaucobilin (mesobilivardin) ($C_{33}H_{38}O_6N_4$)	M / E / M / P / P / M / M / E H / H / H / H / H / OH	Grn.-blue col.; MP free substances = 316-318°C, dimath. est. = 214-232°C; s. hot ms. al., dil. alk.; sl. s. sth., chl., dil. HCl; i.w.	5% HCl/methyl alcohol	670(30.9) 363(46.8) 309(17.8)	+ / - / - / + / - / -	Glaucobilin or ralatad bilatrienas prasent in hemolymph and integuments of insects (colaoptaras, mollusks, annalids). Sc raaction with iodina asma as for masobilirubin.
Biladienones						
11 Bilichrysin ($C_{33}H_{34}O_7N_4$) and maso compound	M / V / M / P / P / M / M / V H / H / H_2 / H / O / O	Yel. col. MP; (masobilichrysin) = 240°C.	Mesobilichrysin in NH_3/alcohol	416(40.5) 311(23)	(+) / (+) / - / + / (+) / + red fluorescence	Isomarization product of bilipurpurin.
12 Bilipurpurin ($C_{33}H_{34}O_7N_4$) and ralatad compounds	M / V / M / P / P / M / M / V H / H / H / H / O / H / OH	Rad-purp. col.	Zn complex in alcohol Maso compound	635-645 619-630	- / - / - / + / - / - rad fluorescance	Purpla stage of Gmalin raaction and othar oxidations of bilirubins and bilvardin. Rasamblas biliviolina.
Bilanediones						
13 Cholatalin ($C_{33}H_{34}O_8N_4$) and ralatad compounds	M / V / M / P / P / M / M / V H / O / H / H / O / H / OH	Yal. col.	HCl/alcohol Zn complex in alcohol	490-495 505-515	- / - / - / + / + / - grn. fluorescance	Yallow stage of Gmalin raaction and othar oxidations of bilirubin, bilivardin, bilipurpurin. Rasamblas urobilina.
Dipyrrl Compounds						
14 Probilifuscins, bilifuscins, propentdyopents ($C_{16}H_{18}$-$_{20}O_4$-$_5N_2$)	Not definitely astablished; probably dihydroxy-dipyrrl methanes and their oxidation products.	Colori. except bilifuscina, which ara brown polymarisation and oxidation products of probilifuscina. Propentdyopents ara rad in NaOH-$Na_2S_2O_4$ (pentdyopent).	Charactaristic absorption banda in NaOH-$Na_2S_2O_4$ at about 525 (523-525) account for nama "pent-dyopent."		No charactaristic raaction.	Secondary products of oxidation of bila pigments and hamatin compounds, excreted in urina and faeas in jaundica and livar disaasa; present in gallstonas.

/1/ Abbraviations: ac.a. = acatic acid; acat. = acatona; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = banzana; chl. = chloroform; col. = color; colori. = colorless; cryst. = crystal(line); dil. = dilute; dimath. = dimathyl; est. = astar; eth. = ether; eth. ac. = athyl acatata; glac. = glacial; grn. = green; i. = insoluble; MP = malting point; me. = methyl; or. = orange; purp. = purple; pyr. = pyridine; sl. = slightly; s. = soluble; vit. = violat; w. = water; yel. = yallow. /2/ λmaximum in mμ = wava langth of maximum absorption; figuras in parenthasas ara ε $\frac{mM}{1cm}$, i.a., extinction coefficients of millimolar solutions of 1 cm thicknass. /3/ Oxidation product of bilirubin.

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS



	Pigmeot	Melting Point, °C[1]	Hydroxyl Position, C-	Methoxyl Position, C-	Source
			Flavones		
1	Acacetin	261 (203)	5, 7	4'	Robinia pseudoacacia (leaves).
2	Acranmerin	350 (232)	5, 7, 3', 4', 5'	8	Gleditsia triacanthos (pods).
3	Apigenin	348 (182)	5, 7, 4'		Parsley (leaves, stems, flowers), Dahlia spp (white flowers).
4	Baicalein	266 (192)	5, 6, 7		Scutellaria baicalensis (roots).
5	Chrysin	275 (192)	5, 7		Populus monilifera balsamifera (buds), Oroxylum indicum (bark).
6	Chrysoeriol	325 (215)	5, 7, 4'	3'	Eriodictyon glutinosum.
7	Diosmetin	255 (196)	5, 7, 3'	4'	Scrophularia nodosa, Dahlia variabilis.
8	Flavone	100			Primula spp.
9	Fukugetin	5, 7, 3', 4'	5, 7, 3', 4'	(6-epoxy-p-hydroxy-cinnamoyl)	Garcinia spicata (bark), Xanthocymus ovalifolia (bark).
10	Genkwanin	286 (198)	5, 4'	7	Daphne genkwa (flowers), Prunus puddum (bark).
11	5-Hydroxy-7, 4'-methoxyflavone	175 (199)	5	7, 4'	Betula spp (leaf buds).
12	Lotoflavin	300 (178)	5, 7, 2', 4'		Lotus arabicus.
13	Luteolin	331 (226)	5, 7, 3', 4'		Chrysanthemum indicum (flowers), Digitalis purpurea (leaves), celery (seeds).
14	Nobiletin	134		5, 6, 7, 8, 3', 4'	Citrus nobilis (fruit peel).
15	Oroxylin-A	232 (132)	5, 7	6	Oroxylum indicum (root bark).
16	Pectollinarigenin	216 (151)	5, 7	6, 4'	Linaria vulgaris (flowers).
17	Primetin	231 (189)	5, 8		Primula modesta (leaves).
18	Primuletin	157 (145)	5		Primula spp.
19	Scutellarein	350 (237)	5, 6, 7, 4'		Scutellaria altissima (flowers, leaves), Galeopsis tetrahit, Teucrium chamaedrys.
20	Tectochrysin	163 (149)	5	7	Populus pyramidalis, P. nigra (buds), Pinus strobus (heartwood).
21	Tricin	292 (254)	5, 7, 4'	3', 5'	Triticum dicoccum (leaves).
22	Wogonin	203 (153)	5, 7	8	Scutellaria baicalensis.
			Flavonols		
23	Auranetio	140		3, 6, 7, 8, 4'	Citrus aurantium (fruit peel).
24	Ayanun	173 (177)	5, 3'	3, 7, 4'	Diethemonanthus benthamianus (heartwood).
25	Datiscetin	276 (141)	3, 5, 7, 2'		Datisca cannabina (leaves), Psecnia albiflora var. hortensis.
26	Erianthin	156 (163)	5, 7	3, 6, 8, 3', 4'	Blumea eriantha (flowers).
27	Fisetin	330 (200)	3, 7, 3', 4'		Rhus spp, Quebracho colorado (wood).
28	Galangin	215 (144)	3, 5, 7		Alpinia officinarum (rhizome).
29	Galangin monomethyl ether	299 (176)	5, 7	3	A. officinarum (rhizome),
30	Gardenin	162 (136)	5	3, 6, 8, 3', 4', 5'	Gardenia lucida (gum).
31	Gossypetin	314 (230)	3, 5, 7, 8, 3', 4'		Gossypium spp, Hibiscus spp (flowers).
32	Herbacetin	283 (193)	3, 5, 7, 8, 4'		Gossypium indicum, G. herbaceum (flowers).
33	Hibiscetin	350 (244), 360 (dec.)[2]	3, 5, 7, 8, 3', 4', 5'		Hibiscus sabdariffa (flowers).
34	Icaritin	240 (147)[2]	3, 5, 7	4'-(8-γ-hydroxy-isoamyl)	Epimedium macranthum.
35	Isorhamnetin	305 (205)	3, 5, 7, 4'	3'	Cheiranthus cheiri, Trifolium pratense, Cassia scutifolia, etc.
36	Isalpinin	195 (171)	3, 5	7	Alpinia spp (seeds).
37	Kanugin	205		3, 7, 3'-(4', 5'-methylenedioxy)	Pongamia glabra.

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /2/ Tetraacetate.

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS (Continued)

	Pigment	Melting Point, °C[1]	Hydroxyl Position, C-	Methoxyl Position, C-	Source
			Flavonols (concluded)		
38	Karanjin	159		3 ([7, 8:5', 4'] - furano)	Pongamia glabra.
39	Kaempferide	229 (195)	3, 5, 7	4'	Alpinia officinarum (rhizomes)
40	Kaempferol	278 (181)	3, 5, 7, 4'		Robinia pseudoacacia (flowers), Indigofera arrecta (leaves), Gossypium herbaceum, etc.
41	Melisimplexin	185		3, 5, 6, 7 (3', 4'-methylenedioxy)	Melicope simplex (bark).
42	Melisimplin	235 (202)	5	3, 6, 7 (3', 4'-methylenedioxy)	Melicope simplex (bark).
43	Meliternatin	199		3, 5 (6, 7, 3', 4'-di-methylenedioxy)	Melicope ternata (bark).
44	Meliternin	186		3, 5, 7, 8 (3', 4'-methylenedioxy)	Melicope ternata (bark).
45	Morin	290 (145)[3]		3, 5, 7, 2', 4'	Chlorophora tinctoria (wood).
46	Myricetin	361 (216)	3, 5, 7, 3', 4', 5'		Myrica magi, M. rubra (bark), Ampelopsis meliscfolia.
47	Nor-β-anhydroicaritin[4]	305 (212)	3, 5, 4'	(2'', 2''-dimethyl-[7, 8:6'', 5''] -chromano)	Phellodendron amurense (leaves).
48	Ombuin	230 (212)	3, 5, 3'	7, 4'	Phytolacca dioica (leaves).
49	Patuletin	264 (172)	3, 5, 7, 3', 4'	6	Tagetes patula (flowers).
50	Quercetagetin	320 (211)	3, 5, 6, 7, 3', 4'		Tagetes patula, T. erecta (flowers).
51	Quercetin	317 (194)	3, 5, 7, 3', 4'		Quercus tinctoria (bark), Prunus serotina, Helianthus annus, etc.
52	Rhamnazin	216 (155)	3, 5, 4'	7, 3'	Polygonum hydropiper, Rhamnus infectoria.
53	Rhamnetin	296 (192)	3, 5, 3', 4'	7	Rhamnus catharica.
54	Rhamnocitrin	222 (201)	3, 5, 4'	7	Rhamnus catharica (fruit).
55	Robinetin	330 (224)	3, 7, 3', 4', 5'		Robinia pseudacacia, Gleditsia monosperma (wood).
56	Tambuletin	271 (142)	3, 5, 7, 4'	8	Xanthoxylum scanthopodium (seeds).
57	Tambulin	205 (165)	3, 5	7, 8, 4'	Z. acanthopodium (seeds).
58	Tangeretin	154		3, 5, 6, 7, 4'	Citrus nobilis deliciosa (fruit peel).
59	Ternatin	211 (166)	5, 4'	3, 7, 8, 3'	Melicope ternata (bark).
60	Thapsin (Calycopterin)	226 (129)	5, 4'	3, 6, 7, 8	Digitalis thapsi, Calycopteris floribunda (leaves).
61	Biochanin-A (Olmelin)	212 (190)	5, 7	4'	Cicer arietenum (seeds), Gleditsia triacanthos.
62	Daidzein	323 (187)	7, 4'		Soja hispida (seeds).
63	Ferreirin	212	5, 7, 2'	4'	Ferreirea spectabilis (heartwood)
64	Formononetin	257 (170)	7	4'	Ononis spinosa.
65	Genistein	291 (202)	5, 7, 4'		Genista tinctoria (shoots), Soja hispida (seeds).
66	Homoferreirin	168 (137)	5, 7	2', 4'	Ferreirea spectabilis (heartwood).
67	Irigenin	185 (128)	5, 7, 3'	6, 4', 5'	Iris florentina (rhizome)
68	Muningin	285 (233)	6, 4'	5, 7	Pterocarpus angolensis (heartwood).
69	Orobol	271 (212)	5, 7, 3', 4'		Orobus tuberosus.
70	Osajin	193 (152), 162)[5]	5, 4'	(6-isopentenyl-2'', 2''-dimethyl-[7, 8:6'', 5''] -pyrano)	Maclura pomifera.
71	Pomiferin	201 (154)	5, 3', 4'	(6-isopentenyl-2'', 2''-dimethyl-[7, 8:6'', 5''] -pyrano)	M. pomifera.
72	Prunetin	242 (225)	5, 4'	7	Prunus spp (bark), Pterocarpus angolensis.
73	Pseudobaptigenin	299 (173)	7	(3', 4'methylenedioxy)	Baptisia spp (root).
74	Santal	223 (170)	5, 3', 4'	7	Santalum album (wood), Baphia nitida.
75	Tectorigenin	227 (190)	5, 7, 4'	6	Iris tectorum, Belamcanda chinensis (rhizomes).
			Flavanones		
76	Alpinetin	225	7	5	Alpinia chinensis.
77	Butin	215 (131)	7, 3', 4'		Butea frondosa (flowers).
78	Citronetin	225 (119)	5, 7	2'	Citrus limonum (fruit peel).
79	Cryptotrobin	203	5, 7	(6-methyl)	Pinus strobus (heartwood).
80	Desmethoxymatteucinol	203 (162)[6]	5, 7	(6, 8-dimethyl)	Matteucia orientalis.
81	Eriodictyol	267 (137)	5, 7, 3', 4'		Eriodictyon spp (leaves).
82	Hesperetin	228 (82)	5, 7, 3'	4'	Citrus spp (fruit peel)
83	Homoeriodictyol	225 (163)	5, 7, 4'	3'	Eriodictyon glutinosum (leaves).
84	Isosakuranetin	194 (140)	5, 7	4'	Citrus trifoliata (flowers).
85	Liquiritigenin	207 (186)	7, 4'		Glycyrrhiza glabra var glandilifera.
86	Matteucinol	174 (170)	5, 7	4' (6, 8-dimethyl)	Matteucia orientalis
87	8-Methoxybutin	197 (124)	7, 3'4'	8	Coreopsis grandiflora (flowers)
88	Naringenin	251 (127)	5, 7, 4'		Citrus decumana (fruit peel), Salix purpurea (bark), Prunus serotina (heartwood),
89	Pinocembrin	195	5, 7		Pinus cembra, P. montana, P. banksiana (heartwood).
90	Pinostrobin	102	5		Pinus strobus (heartwood)
91	Plathymenin	229 (151)	6, 7, 3', 4'		Plathymenia reticulata (wood).
92	Ponkanetin	152		5, 6, 7, 8, 4'	Citrus poonensis (unripe fruit peel).
93	Sakuranetin	154 (97)	5, 4'	7	Prunus spp (bark).
94	Strobopinin	227	5, 7	(8-methyl)	Pinus strobus (heartwood).
			Chalcones C), Dihydrochalcones (D), Bentophenones (B)		
95	Butein (C)	215 (131)	3, 4, 2', 4'		Coreopsis douglasii, Dahlia variabilis (flowers).
96	Isocarthamin (C)	228	4, 2', 3', 4', 6'	(3'-glucoside)[7]	Carthamus tinctorius (flowers).
97	Isosalipurposide (C)	173	4, 2', 4', 6'	(2'-glucoside)[8]	Salix purpurea (old bark).
98	Lanceoletin (C)	(166)	3, 4, 2', 4'	3'	Coreopsis lanceolata, C. saxicola (ray flowers).
99	Lonchocarpin (C)	108	2'	(2'', 2''-dimethyl-[5'', 6'': 3', 4'] -pyrano)	Lonchocarpus sericeus (seeds and roots).
100	Pedicellin (C)	98		2', 3', 4', 5', 6'	Didymocarpus pedicellata (leaves).
101	Pedicin (C)	145 (183)[9]	2', 5'	3', 4', 6'	D. pedicellata (leaves).

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /3/ 3, 7, 2', 4-Tetraacetate. /4/ Aglucone of amurensin. /5/ Acetate exists in two forms. /6/ Mono-(probably 7-)acetate. /7/ Forms isocarthamidin (5, 6, 7, 4'-tetrahydroxyflavanone) when hydrolyzed. /8/ Forms naringenin (5, 7, 4'-trihydroxyflavanone) when hydrolyzed. /9/ Dibenzoate.

27. PLANT PIGMENTS: OCCURRENCE, PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS (Concluded)

	Pigment	Melting Point, °C[1]	Hydroxyl Position, C-	Methoxyl Position, C-	Source
			Chalcones (C), Dihydrochalcones (D), Benzophenones (B) (concluded)		
102	Stillopeidin (C)	232 (156)	3, 4, 2', 4', 5'		Flathymenia reticulata (wood), Coreopsis stillmanii (flowers).
103	Strobochrysin (C)		2', 4', 6'	(5-methyl)	Pinus strobus (heartwood).
104	Asebogenin (D)	168 (77)	4, 2', 6'	4'	Andromeda japonica (leaves).
105	Phloretin (D)	264 (165)	4, 2', 4', 6'		Micromelum teprocarpum, root bark of fruit trees
106	Cotoin (B)	131 (94)	2, 6	4	Coto spp (bark).
107	Hydrocotoin (B)	98	2	4, 6	Coto spp (bark).
108	p-Hydroxybenzophenone	134 (81)	4		Talauma mexicana (leaves).
109	Maclurin (B)	222	2, 4, 6, 3', 4'		Morus tinctoria (wood)
110	Methylhydrocotoin (B)	115		2, 4, 6	Paracoto spp (bark).
111	Methylprotocotoin (Hydroxyleucotin) (B)	135		2, 4, 6(3', 4'-methylenedioxy)	Coto spp (bark).
112	Protocotoin (B)	142	2	4, 6 (3', 4'-methylenedioxy)	Coto spp (bark).
			Xanthones (X), Chromones (C), Aurones (A)		
113	Decussatin (X)	150 (167)	8	3, 4, 7	Swertia decussata (flowers).
114	Desmethylswertianol (X)	317	1, 3, 5, 8		Swertia toszensis (roots).
115	Euxanthone (X)	240 (185)	1, 7		Plationia insignis (heartwood).
116	Gentisin (X)	267 (197)	1, 7	3	Gentiana lutea, Swertia japonica (roots).
117	Jacareubin (X)	257 (213)	1, 5, 6	(2', 2'-dimethyl-[5', 6':2, 3] -pyrano)	Calophyllum brasiliense (heartwood).
118	Lichexanthone (X)	187	1	3, 6 (8-methyl)	Parmella formoesana, P. quercina.
119	Ravenelin (X)	268 (205)	1, 4, 8	(3-methyl)	Metabolite of Helminthosporium ravenelii curtis and H. turcicum passerini.
120	Swertianol (X)	267 (240)	1, 3, 8	5	Swertia toszensis, S. japonica (roots)
121	Swertinin (X)	217 (157)	1, 2	5, 6	Swertia decussata (stems)
122	Angustifolionol (C)	118	5	7(6, 6, 8-trimethyl)	Buchousia angustifolia (oil).
123	Chellol (C)	178		5 (2-hydroxymethyl-[2', 3':6, 7] -furano)	Ammi visnaga (seeds).
124	Eugenin (C)	120 (154	5	7 (2-methyl)	Eugenia aromatica (flowers).
125	Eugenitin (C)	162 (177)	5	7 (2, 6-dimthyl)	E. caryophyllata (flowers).
126	Isoeugenitol (C)	230 (151)	5, 7	(2, 8-dimethyl)	E. caryophyllata (flowers).
127	Khellin (C)	155		5, 8 (2-methyl-[2', 3':6, 7] -furano)	Ammi visnaga (seeds).
128	Peucenin (C)	212	5, 7	(2-methyl-6-iso-propoxyl-2)	Peucedanum ostruthium (wood).
129	Visnagin (C)	145		5 (2-methyl-[2', 3':6, 7] -furano)	Ammi visnaga (seeds).
130	Aureusidin (A)	295 (185)	4, 6, 3', 4'		Anturrhinum majus, Oxalis cernua (yellow flowers).
131	Leptosidin (A)	256 (166)	6, 3', 4'	7	Coreopsis grandiflora (flowers).
132	Sulfuretin (A)	312 (194)	6, 3', 4'		Cosmos sulfureus, Dahlia variabilis (yellow flowers).
	Pigment	Melting Point, °C[1]	Hydroxyl Position, C-	Optical Rotation[1][2]	Source
			Flavanonols		
133	Alpinone	178 (118)	3, 5 (7-methoxyl, 2-methyl)	+79 (pyridine)[1]	Nothofagus dombeyi, Prunus serotina (heartwood), Cercidiphyllum japonicum.
134	Ampelopsin	246 (175)	3, 5, 7, 3', 4', 5'		Ampelopsis meliaefolia kudo.
135	Dihydrorobinetin	228 (143)	3, 7, 3', 4', 5'	+13.8 (acetone)	Robinia pseudoacacia (wood).
136	Fustin	218 (151)	3, 7, 3', 4'		Rhus cotinus, Quebracho colarado (wood).
137	Katsuranin	241	3, 5, 7, 4'	+45 (acetone + water)	Cercidiphyllum japonicum, Nothofagus dombeyi, Prunus serotina.
138	Phellamuretin	220 (199)	3, 5, 4' (2'', 2''-dimethyl-[7, 8:6'', 5''] -chromano)		Phellodendron amurense.
139	Pinobanksin	178	3, 5, 7	+14.4 (methanol)	Pinus spp (heartwood).
140	Taxifolin	242 (130)	3, 5, 7, 3', 4'	+46 (acetone + water), +13 (ethanol)	Pseudotsuga menziesii (heartwood), Larix decidua (heartwood).
141	Pinobanksin 7-methyl ether	181	3, 5 (7-methoxyl)	-20 (chloroform)	Pinus clausa (heartwood).

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /10/ Determined at 20°C unless otherwise specified.
/11/ Determined at 29°C.

Part II: CHARACTERISTIC REACTIONS OF SOME FLAVONOID TYPES

	Type	Cold Alkali	Hot Alkali	Concentrated H_2SO_4	Ferric Chloride	Mg-HCl[1]	Lead Acetate
1	Flavones	Yellow to red-orange	Yellow to red-orange	Lemon or green yellow		Red-orange	Yellow ppt
2	Flavonols	Yellow	Yellow	Yellow to green and blue-green (some fluoresce)	Olive-green	Pink to red	Orange-yellow ppt
3	Chalcones	Red	Blue-red	Yellow to orange	Brown	No color change	Brick-red ppt
4	Aurones	Red[2]	Red[3]	Red[3]	No color change	No color change	
5	Flavanones	Colorless	Red	Red to yellow		Red-violet to blue-violet	Very light yellow to yellow ppt

/1/ Small piece of magnesium ribbon or turnings is placed in an alcoholic solution of the compound, and a few drops of concentrated hydrochloric acid are added. /2/ Deep purple if the 6-hydroxyl position is not free (as in a methyl ether, etc.). /3/ Yellow-orange if there is no 4'substituent.

Part III: ALGAL PIGMENTS: PHYSICAL CONSTANTS

	Pigment[1]	Absorption Maxima ($m\mu$) and Specific Extinction Coefficients	Fluorescence Emission Maxima ($m\mu$)	Molecular Weight	Isoelectric pH	Abs. max. ($m\mu$) of Chromophore (in acid $CHCl_3$)[1]	Source
1	R-Phycoerythrin	495 540 565 (E_{sp}5.68) (E_{sp}6.50) (E_{sp}7.92)	580	290,000	4.3	576	Ceramium rubrum; Porphyra spp
2	C-Phycoerythrin	563				576	Phormidium fragile; Nostoc sp
3	R-Phycocyanin	550 (E_{sp}4.06) (E_{sp}6.35)	630-6/90	272,000	4.85		Ceramium rubrum; Porphyra perforata
4	C-Phycocyanin	615 637 (E_{sp}5.74)	637	208,000	4.7	630	Lyngbya lagerheimii; Arthrospira sp

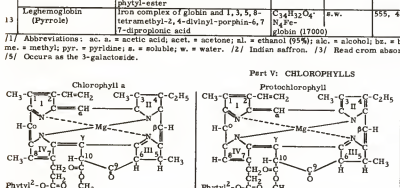
/1/ All are soluble in dilute salt solutions and precipitated by 10-20% $(NH_4)_2SO_4$.

Part IV: SOME GENERAL TYPE CHARACTERISTICS

	Common Name and (Type Compound)	Chemical Constitution	Molecular Formula and (Weight)	Solubility[1]	Absorption Maxima[1] mμ	Source
			Carotenoids			
1	Beta-carotene	[1,1'9-Di-(β-iono)-3,7,12,16-tetra-methyl-octo-deca-neone-2,4,6,8,10,12,14,16,18]-polyene	$C_{40}H_{56}$ (536)	$n.CS_2$, chl. bz.	520, 485, 450 in CS_2; 497, 466 in chl.	Widely distributed in plants together with chlorophyll and xanthophyll.
2	Xanthophyll	[1'-(3-Hydroxy-β-iono)-3,7,12,16-tetramethyl-octo-deca-neone-2,4,6,8,10,12,14,16,18]-polyene	$C_{40}H_{56}O_2$ (568)	e.chl., acet., eth., bz.	508, 475, 445 in CS_2; 487, 456, 428 in chl.	See carotene above.
			Diaroyl Methane			
3	Curcumin[2]	1,7-Di(4-hydroxy-3-methoxy-phenyl)-heptadiene-1,6-dione-3,5	$C_{21}H_{20}O_6$ (368)	e.eth.	425[3] in al.[4]; 667, 625, 615, 385, 294 (solid state).	←Roots, shoots of Curcuma tinctoria.
			Carbocyclic Compounds			
4	Atromentin (Benzoquinone)	2,5-Di(p-hydroxyphenyl)-3,6-di-hydroxy-1,4-benzoquinone	$C_{18}H_{12}O_6$ (324)	a.al., amyl alc., eth.	No characteristic absorption spectrum.	←Fungus Paxillus atro-tomentosus.
5	Vitamin K$_1$ (Naphthoquinone)	2-Methyl-3-(3,7,11,15-tetramethyl-hexadecene-2)-naphthoquinone-1,4	$C_{31}H_{46}O_2$ (324)	e.eth., acet., hexane	325, 270, 260, 249, 243 in hexane.	←Leaves of plants; microorganisms.
6	Alizarin (Anthracene)	1,2-Dihydroxyanthraquinone	$C_{14}H_8O_4$ (240)	e.al., eth., bz.	388, 250[3] in al.	←Roots of Olenlandia umbellata.
7	Theliphoric acid (Phenanthrene)	(3,4'-Dihydroxy-3'-carboxyl-5,6'-dione-4,1'-diphenyl)-1-(2,4-pentadienoic acid)	$C_{20}H_{16}O_5$ (336)	s.pyr.	495 in pyr.	←Various spp of Telephora.
			Heterocyclic Compounds Containing Heterocyclic Oxygen			
8	Usnic acid (five-membered ring)	[(Phenyl-1-[ethanone-1]-2,4-dihydroxy-3-methyl-[furyl-5,6]-2-methyl-3-hydroxy-4-[ethanone-1]-5-carbonyl)-cyclohexadiene-3,6	$C_{18}H_{16}O_7$ (344)	w.al., eth., bz.	Not available.	←Various spp of Usnea, Parmelia, Leganora.
9	Flavone (six-membered ring)	2-Phenyl-chromone	$C_{15}H_{10}O_2$	a.al., eth., w.	298, 250 in al.	←Leaves, flower stems, seed capsules of some Primulae spp.
10	Polargonidin[2] (six-membered ring)	3,5,7,4'-Tetrahydroxy-flavone	$C_{15}H_{11}O_5$	a.ac.a., al., butanol	500, 420[3] in w.; 530, 420[3] in al.	←Asters and carnations.
			Compounds Containing Heterocyclic Nitrogen			
11	Indigo (Indole)	1,2-Di-(3-carbonyl-2-indole)-ethene	$C_{16}H_{10}O_2N_2$ (262)	a.h.chl., h. aniline	591 in xylol.	Various spp of Indigofera; Polygonum tinctorium.
12	Chlorophyll a (Pyrrole)	Mg-complex of 1,3,5,8-tetramethyl-4-ethyl-2-vinyl-9-oxo-10-carbmeth-oxy-phorbine-7-propionic acid-phytyl-ester	$C_{55}H_{72}O_5N_4Mg \cdot H_2O$ (901)	e.eth., acet., me.alc.	See table below.	Chloroplasts of green plants.
13	Leghemoglobin (Pyrrole)	Iron complex of globin and 1,3,5,8-tetramethyl-2,4-divinyl-porphin-6,7-dipropionic acid	$C_{34}H_{32}O_4N_4Fe$ (17000)	n.w.	555, 485 in w.	Root nodules of leguminous plants.

[1] Abbreviations: ac. a. = acetic acid; acet. = acetone; al. = ethanol (95%); alc. = alcohol; bz. = benzene; chl. = chloroform; eth. = ether; h. = hot; me. = methyl; pyr. = pyridine; s. = soluble; w. = water. [2] Indian saffron. [3] Read crom absorption curve. [4] Undergoes changes in solution.

Part V: CHLOROPHYLLS



	Pigment	Absorption Maxima[3] In Ether mμ	Absorption Maxima[3] Phaeophytin[4] in Ether mμ	Fluorescence Maxima[3] In Ether mμ	Fluorescence Maxima[3] Phaeophytin[4] in Ether, mμ	Principal Source	Remarks
1	Chlorophyll a	660, 617, 575, 430, 410.	668, 612, 564, 543, 506, 412.	668, 723	672.5, 715	All photosynthetic tissues except photosynthetic bacteria.	
2	Chlorophyll b	640, 595, 535, 455.	655, 600, 545, 525, 436.	649, 708,	657, 707	Photosynthetic tissues of higher plants, ferns, mosses, chlorophycese, (green algae) Euglenineae and some diatoms[7].	When present, represents about 20-40% of the total chlorophylls.
3	Chlorophyll c (Chlorofucin)	627, 579.5 545, 446.	640, 595, 565, 525, 420.	629, 690.	649, 719.	Diatoms, dinoflagellates, (Dinophycese) and brown algae (Phaeophycese).	Probably phytyl-free.
4	Chlorophyll d	686, 645, 595, 545, 445, 390.	690, 636, 545, 520, 425, 380.	696, 752.	701.	Red algae especially (Rhodochorton nothii).	Contains phytyl residue and the cyclopentanone ring.
5	Chlorophyll e	654, 415 (in methanol).				Yellow-green algae (Tribonema bombycinum).	
6	Protochlorophyll	623, 571, 535, 432.		627, 685 (in acetone)		Etiolated seedlings.	Probable precursor of the chlorophylls.
7	Bacteriochlor-[5]	770, 708, 574, 390, 365.	754, 686, 612, 528, 492, 385, 367.			All purple sulfur and non-sulfur photosynthetic bacteria.	
8	Chlorobium Chlorophyll (Chlorovitridin)	764, 659, 624, 431, 408.	760, 660, 604, 549, 515, 412			Green sulfur photosynthetic bacteria (Chlorobium spp).	Not identical with bacteriochlorophyll.

[1] Structure is still tentative. [2] Phytol = $(CH_3)_2-CH(CH_2)_3-CH-(CH_2)_3-CH(CH_3)_3-C=CH-CH_2OH$. [3] Principal maxima underlined. [4] The magnesium-free pigment.

28. PLANT RESINS: SOURCE, PHYSICAL AND CHEMICAL CHARACTERISTICS

Data are approximations and may vary depending upon the history of the sample.

	Substance	Source	Specific Gravity	Softening Point, °C	Melting Point, °C	Acid Number	Saponification Number	Iodine Number	Solvent
1	Accra copal	Copaifera sp	1.033	75	120	98	140	58	Amyl alcohol, aniline
2	Accroides	Xanthorrhoea spp	1.34	75	110	64-106	65	200	Alcohol, esters, ketones
3	Amber	Fossils of Pinaceae	1.05-1.10	175	250-315	15-35	85-150	62	Turpentine oil, CS_2
4	Animé copal	Fossils	1.03		230	18-27	60-90	128-137	
5	Benguela copal	Copaifera demeusei	1.06	65	165	123	157	61-85	Amyl alcohol, aniline
6	Benzoin[1]	Storax (Styrax benzoin)	1.09		>100	75-100	190-207	57-76	Ethyl alcohol, acetone
7	Boea manlia	Agathis alba'	1.07	79-80	130-132	118-141	143-175	110-137	Ethyl alcohol, ketones
8	Brazil copal	Hymenaea courbaril	1.053	50	100	123	133	123-134	Amyl alcohol, aniline
9	Cameron copal	Copaifera demeusei	1.052	100	150	160	70	65-70	Aniline, ether
10	Colombia copal	Hymenaea spp	1.054	90	<300	119	156		Amyl alcohol, aniline
11	Congo copal	Copaifera demeusei	1.06	90	128	100	124	115	Amyl alcohol, amyl acetate, aniline
12	Damar, Batavia	Shorea spp, Hopea spp	1.03-1.06	70-76	99-110	22-23	29-39	95-127	Chloroform, benzene
13	Demerara copal	Hymenaea courbaril	1.047	90	180	98	102		Ether[2], chloroform[2], aniline[2]
14	Dragon's blood	Daemonorhops draco	1.25		100	11	153	54-98	Alcohol, ether, benzene
15	Elemi, Manila	Canarium luzonicum	1.02-1.05		75	20-35	21-44	118	Esters
16	Guaiacum	Guaiacum officinale	1.2		85-90	20-53	74-84		Ether[3]
17	Jalap	Exogonium purga	1.14		150	12-27		132	Ethyl alcohol
18	Kauri, pale	Kauri-pine (Agathis australis)	1.06	90-130	127-134	57-81	67-117	82-154	Amyl alcohol[2], aniline[2]
19	Kissel copal	Copaifera demeusei	1.066	65	110	70	118		Aniline
20	Madagascar copal	Trachylobium verrucosum	1.056	130	300	66	78	126	Amyl alcohol[2], aniline[2]
21	Manila hard	Agathis alba	1.07	79-80	130-132	118-141	143-175	110-137	Amyl alcohol, aniline
22	Manila soft	A. alba	1.06	77-88	121	127-134	158-190	121-126	Alcohol
23	Mastic	Pistacia lentiscus	1.04-1.07	55	76	50-70	62-90	64-124	Amyl alcohol, ether, benzene
24	Pontianak	Agathis alba	1.07-1.08	82-135	126-169	112-121	148-180	119-142	Alcohol, hydrocarbons
25	Red Angola copal	Copaifera demeusei	1.066	90	305	128	132	63-137	Amyl alcohol, acetone
26	Rosin	Pine, longleaf (Pinus palustris)	1.07-1.09	70-80	120-135	150-175	167-194	80	Organic solvents
27	Sandarac	Arara-tree (Callitris quadrivalvis)	1.05-1.09	100-130	135-150	117-155	145-157	112-141	Alcohol, ether
28	Sierra Leone copal	Copaifera copalifera	1.072	60	130	110	123	63-133	Amyl alcohol, aniline
29	White Angola copal	Copaifera demeusei	1.055	45	95	127	160	130	Amyl alcohol, acetone
30	Zanzibar copal	Trachylobium verrucosum	1.054	150	300	93	93	115-123	Amyl alcohol[2], amyl acetate[2]

/1/ A balsam. /2/ Partly soluble. /3/ 54-74% solubility.

29. PLANT TANNINS: SOURCE AND CHEMICAL CHARACTERISTICS

Plant tannins are polyphenols, within plant extracts, capable of converting the collagen in hides and skins into non-putrescible leather. Varying quantities of mono- and disaccharides, gums and various phenols are associated with the tannin in the extract, but are not alone capable of forming the conversion. There are two main categories of tannins, generally but not absolutely valid: HYDROLYZABLE, hydrolyzed by HCl or enzymes into sugars and phenolic carboxylic acids, and CONDENSED, converted by hot HCl into more highly condensed and insoluble red "phlobaphenes" or tanners' red, " constitution unknown.

Part I: HYDROLYZABLE TANNINS

	Tannin[1]	Empirical Formula	Source	Present in Commercial Extract	Constitution and Hydrolysis Products
1	Acertannin	$C_{20}H_{20}O_{13}\cdot 2H_2O$	Acer ginnala (leaves)		Digalloylaceritol 2 gallic acid + aceritol
2	Brevilagin		Caesalpinia brevifolia (pods)	Algarobilla (brevifolin carbonic acid)	Glucose + ellagic acid + $C_{13}H_8O_8$
3	Chebulagic acid	$C_{41}H_{39}O_{27}\cdot 10H_2O$	Terminalia chebula (fruit) Caesalpinia coriaria (pods)	Myrobalan and divi-divi	Glucose + gallic acid + ellagic acid + chebulic acid ($C_{14}H_{12}O_{11}$)
4	Chebulinic acid	$C_{41}H_{32}O_{27}\cdot 2H_2O$	Terminalia chebula (fruit)	Myrobalan	Glucose + 3 gallic acid + chebulic acid ($C_{14}H_{12}O_{11}$)
5	Corilagin	$C_{27}H_{22}O_{18}$	Terminalia chebula (fruit)	Myrobalan and divi-divi	Glucose + gallic acid + ellagic acid
6	Dehydrodigallic acid	$C_{14}H_{10}O_{10}$	Castanea vesca (leaves, shoots[2])		Gallic acid
7	Ellagic acid	$C_{14}H_6O_8$	Quercus sp[3] (galls)	Divi-divi, algarobilla, myrobalan, valonia, chestnut	4, 5, 6, 4', 5', 6'- Hexahydroxy-diphenic acid - 8,8-dilactone
8	Hamamelli tannin	$C_{20}H_{20}O_{14}\cdot 6H_2O$	Hamamelis virginiana (bark)		Digalloylhamamelose 2 gallic acid + hamamelose
9	Tannic acid[4]	$C_{76}H_{52}O_{46}$	Rhus chinensis (galls)	Chinese tannin	Glucose + 10 gallic acid
10	Valonia acid dilactone	$C_{21}H_{10}O_{13}$	Quercus aegilops[5] (acorn cups)	Valonia	Ellagic acid + gallic acid

/1/ Except where indicated, all tannins listed are crystalline. /2/ Young. /3/ Numerous other sources. /4/ Amorphous. /5/ And allied species.

Part II: CONDENSED TANNINS

Condensed tannins are composed of complex mixtures of highly condensed and probably closely related polyphenols, constitution unknown, and lower molecular polyphenolic fractions in which certain constituents are identified. These tannins comprise about 60% of solid commercial plant extracts, associated therein with varying admixtures of "non-tannins."

	Extract	Source	Alkali Fusion Products	Polyphenolic Constituents	Associated Non-tannin Constituents
1	Cube Gambier	Uncaria gambier (leaves)	Phloroglucinol, protocatechuic acid	d-Catechin, dl-epigallocatechin, d-epigallocatechin, quercitin	
2	Cutch	Acacia catechu (wood)	Phloroglucinol, protochechuic acid	l-Catechin, dl-catechin, l-epigallocatechin, dl-epigallocatechin, quercitin	
3	Green tea tannin	Thea sinensis (leaves)		l-Epigallocatechin, d-gallocatechin, d-catechin, l-epigallocatechin gallate, l-catechin gallate, theogallin, quercitin, kaempferol	Sucrose, glucose, fructose, maltose, arabinose, rhamnose, ribose, mesoinositol, gallic acid, anthoxanthins, theanine
4	Quebracho	Schinopsis lorentzii (heartwood)	Resorcinol, protocatechuic acid	Fisetin, ellagic acid	Glucose, arabinose, xylose, gallic acid
5	Wattle (Mimosa)	Acacia mollissima (bark)	Resorcinol, gallic acid; protocatechuic acid, p-resorcylic acid, pyrogallol, phloroglucinol, catechol	Catechin, gallocatechin, fisetin	Sucrose, glucose, fructose, gums

Essential Oil (Botanical Source) Geographical Source	Plant Part, Yield[1] g/100 g	Properties[2]	Chemical Constituents[3]
1 Almond, bitter	Dried, ripe,	Sp gr = 1.042-1.07	Benzaldehyde*, hydrocyanic acid,
2 (Prunus amygdalus)	defatted seed	α_D = 0.0 to +0.17	benzaldehyde cyanohydrin
3 France, Italy, Spain	(0.5-0.7)	n_D = 1.532 - 1.544	
4 Anise seed	Dried, ripe	Sp gr = 0.984-0.994	Acetaldehyde, p-methoxyphenyl-
5 (Pimpinella anisum)	fruit	α_D = -2 to +1	acetone, anethole*, methyl
6 Russia, Germany, France	(1.7-3.1)	n_D = 1.5530-1.5600	chavicol
7 Anise, star	Fruit	Sp gr = 0.98-0.995	d-a- Pinene, anisaldehyde,
8 (Illicium verum)	(2.5-3.0)	α_D = +0.6 to +4.08	p-methoxyphenylacetone, ane-
9 China		n_D = 1.553 - 1.5582	thole*, methyl chavicol
10 Basil, sweet (Ocimum	Flowering	Sp gr = 0.896-0.935	Linalool, methyl chavicol*,
11 basilicum) France,	shoots	α_D = -7.0 to -13.87	cineole
12 Germany, Algeria, Spain	(0.09-0.11)	n_D = 1.477-1.495	
13 Bergamot (Citrus auran-	Fruit rind	Sp gr = 0.881-0.887	d- Limonene, l- linalool, neral,
14 tium bergamia)	(0.5)[4]	α_D = +8.0 to +24.27	l- linalyl acetate*, bergaptene,
15 W. Africa, Italy		n_D = 1.464-1.468	bergaptol
16 Birch, sweet	Twigs	Sp gr = 1.184-1.190	Triacontane(?)($C_{30}H_{62}$), methyl
17 (Betula lenta)	(1.2-1.9)	α_D Inactive	salicylate*, an ester ($C_{14}H_{12}O_2$)
18 Canada, U.S.A.		n_D = 1.5350-1.5380	
19 Bois de Rose (Aniba	Wood	Sp gr = 0.875-0.895	Linalool*, dipentene, terpineol,
20 roseadora) French	(0.7-1.2)	α_D = -4 to +5	nerol, geraniol, p-methylaceto-
21 Guiana, Brazil		n_D = 1.4620-1.4685	phenone, cineole
22 Cade	Wood	Sp gr = 0.956-1.061	d- Cadinene*, d- cadinol, cresol,
23 (Juniperus oxycedrus)	(1.2-1.3)	α_D = +4.3 to +4.7(?)	guaiacol
24 France, Spain		n_D = 1.511-1.514(?)	
25 Calamus (Acorus	Rhizomes	Sp gr = 0.950-1.083	Asarone*
26 calamus) Europe, Asia,	(1.5-4.8)	α_D = -0.9 to +31	
27 North America		n_D = 1.5013-1.5522	
28 Camphor	Wood	Sp gr = 0.954*	a- Pinene, β-pinene, l- linalool,
29 (Cinnamomum camphora)	(1.0-3.0)	α_D = +32.4(?)	camphor*, 1,8-cineole, 1, 4-
30 Formosa, China		n_D = 1.4806(?)	cineole, safrole
31 Caraway	Dried, ripe	Sp gr = 0.907-0.919	d- Limonene, carveol, carvone*,
32 (Carum carvi)	seed	α_D = +70 to +81	dihydrocarvone, d- dihydropinol
33 Holland, Asia	(3-6)	n_D = 1.484-1.488	
34 Cardamom (Elettaria car-	Seeds	Sp gr = 0.923-0.940	Cineole*, terpineol, terpinyl
35 damomum var. a-major)	(3-8.6)	α_D = +20 to +41	acetate, limonene, sabinene(?)
36 Southern India, Ceylon		n_D = 1.461-1.467	
37 Cassia	Leaves,	Sp gr = 1.051-1.069	Cinnamaldehyde*, o-methoxy-
38 (Cinnamomum cassia)	twigs	α_D = -1 to +1	benzaldehyde, methyl-o-coumsral-
39 China	(0.3-0.8)	n_D = 1.6020-1.6135	dehyde, cinnamylacetate, coumarin
40 Catnip	Entire	Sp gr = 0.986-1.081	Nepatilic acid*
41 (Nepeta cataria)	plant	α_D = +1.3 to +13.3	
42 Sicily, U.S.A.	(0.3)	n_D = 1.4872-1.4913	
43 Cedarwood	Heartwood	Sp gr = 0.945-0.960	Cedrene*, cedrenol, cedrol,
44 (Juniperus virginiana)	(2-3)	α_D = -27 to -45	pseudocedrol
45 North America		n_D = 1.5020-1.5070	
46 Celery seed	Seed	Sp gr = 0.878-0.916	d- Limonene*, sedanoic anhydride,
47 (Apium graveolens)	(1.9-2.5)	α_D = +48 to +78	sedanolide, selinene, palmitic
48 Europe, India		n_D = 1.4800-1.4900	acid, guaiacol (?)
49 Cinnamon	Dried bark	Sp gr = 1.016-1.036	Carophyllene, l-a- pinene,
50 (Cinnamomum zeylanicum)	(0.2)	α_D = 0 to -2	l-linalool, cinnamaldehyde*,
51 Ceylon		n_D = 1.5730-1.5910	cuminaldehyde, eugenol
52 Citronella	Dried	Sp gr = 0.898-0.910	Geraniol*, citronellol, camphene,
53 (Cymbopogon nardus)	grass	α_D = -9 to -18	limonene, l- borneol, farnesol,
54 Ceylon	(0.5)	n_D = 1.4790-1.4855	methyl eugenol
55 Citronella	Shoots	Sp gr = 0.882-0.901	Geraniol*, citronellol, cadinol,
56 (Cymbopogon winterianus)	(0.5-2.4)	α_D = -0.47 to -5.75	d- citronellal, methyl eugenol,
57 Java		n_D = 1.463-1.475	geranyl butyrate

Essential Oil (Botanical Source) Geographical Source	Plant Part, Yield[1] g/100 g	Properties[2]	Chemical Constituents[3]
112 Lemongrass, East Indian	Grass	Sp gr = 0.899-0.911	Citral*
113 type (Cymbopogon	(0.2-0.4)	α_D = +1.5 to -5	
114 (Flexuosus) India		n_D = 1.483 - 1.4899	
115 Lemongrass, Java type	Shoots	Sp gr = 0.875-0.900	Myrcene*, geraniol, nerol,
116 (Cymbopogon citratus) W.	(0.2-0.4)	α_D = -3 to +1	a- and β-citral*, methyl
117 Indies, Madagascar, Honduras		n_D = 1.4830-1.4890	heptenone
118 Lime, acid, distilled (Citrus	Fruit	Sp gr = 0.855-0.863*	Bisabolene, d- limonene*, borneol,
119 aurantifolia) E. and W.	(0.3-0.4)[4]	α_D = +34 to +47	l-a- terpineol, n-decylaldehyde,
120 Indies, Florida, Mexico		n_D = 1.4745 - 1.4770	lauric aldehyde, n-octylaldehyde
121 Linoloe	Wood	Sp gr = 0.875-0.898[1]	l- Linalool*
122 (Bulnera delpechiana)	(6-11)	α_D = -14 to -8.2	
123 Mexico		n_D = 1.460-1.466	
124 Mandarin	Fruit	Sp gr = 0.854-0.859	Limonene
125 (Citrus reticulata)	(0.75-0.85)[4]	α_D = +64 to +75	
126 Florida, W.Indies, Sicily		n_D = 1.4745-1.478	
127 Mint	Entire	Sp gr = 0.895-0.909(?)	l- Menthone, l- menthol*,
128 (Mentha arvensis)	plant	α_D = -29 to -43 (?)	isomenthone, l- menthone,
129 Japan, China, Brazil	(1.3-1.6)	n_D = 1.459-1.465(?)	l- menthyl acetate
130 Myrtle (Myrtus communis)	Leaves	Sp gr = 0.881-0.929	Cineole, l- myrtenol, d- myrtenol
131 Southern France, Algeria,	(0.18-0.25)[4]	α_D = +15 to + 27.5	(as ester)*
132 Spain, Asia Minor		n_D = 1.464 - 1.4703	
133 Nutmeg (Myristica fragrans	Dried, ripe	Sp gr = 0.861-0.917	a- Pinene*, borneol, geraniol,
134 E. and W. Indies, Ceylon,	seed	α_D = +8 to +45	d- linalool, myristicin, safrole,
135 Indonesia	(5-16)	n_D = 1.4690-1.4880	eugenol, d--camphene*
136 Orange, bitter (Citrus	Fruit rind	Sp gr = 0.845-0.852[4]	Limonene*, linalool, d-a-
137 aurantium amara)	(0.15-0.33)[4]	α_D = +87 to +96[5]	terpineol, decylaldehyde,
138		n_D = 1.4730-1.4770	acetic acid, cinnamaldehyde
139 Orange, sweet (Citrus	Fruit rind	Sp gr = 0.842-0.846[4]	d- Limonene*, linalool,
140 sinensis) Portugal, Florida	(0.1-0.7)[4]	α_D = +94 to +99[5]	decylaldehyde, citral
141 California, Sicily		n_D = 1.4723-1.4737	
142 Origanum -	Fresh	Sp gr = 0.917-0.955(?)	p-Cymene, d-a-pinene,
143 (Coridothymus capitatus)	plant	α_D = + to +(!?)	a sesquiterpene, carvacrol*,
144 Spain	(0.9)	n_D = 1.499-1.508	thymol
145 Palmrosa	Grass	Sp gr = 0.887-0.900	Geraniol*, farnesol,
146 (Cymbopogon martini var.	(1-1.25)	α_D = +6 to -3	citral, citronellal, formaldehyde,
147 motia) India		n_D = 1.4685-1.4790	acetic acid
148 Patchouly	Dried	Sp gr = 0.950-0.991	Patchouly alcohol, azulene,
149 (Pogostemon cablin)	leaves	α_D = -40 to -72	benzaldehyde, cinnamaldehyde,
150 Java, Singapore	(3.0)	n_D = 1.5060-1.5160	eugenol
151 Pennyroal	Entire	Sp gr = 0.931-0.982(?)	l- a-Pinene, menthol, l- menthone,
152 (Mentha pulegium)	plant	α_D = +15 to +24(?)	d- pulegone*, piperitone, 3-octanyl
153 Spain, Morocco	(1.0)	n_D = 1.483-1.4942(?)	acetate
154 Pepper	Berries	Sp gr = 0.873-0.916	β-Caryophyllene, dl- limonene,
155 (Piper nigrum)	(1-3.2)	α_D = +3 to -16	l-a- phellandrene, a-pinene,
156 India		n_D = 1.480-1.499	piperanal
157 Peppermint	Entire	Sp gr = 0.901-0.913	l- Menthol*, d- menthone,
158 (Mentha piperita)	plant	α_D = -18 to -32	l- menthone, menthofuran,
159 North America, Europe	(0.3-1.0)	n_D = 1.4590-1.4650	dimethyl sulfide
160 Perilla	Blossoms,	Sp gr = 0.923-0.938	Perillaldehyde*
161 (Perilla frutescens)	leaves	α_D = -73 to -96.5	
162 Japan	(0.1-0.15)	n_D = 1.4971-1.5048	
163 Pimenta berry (Pimenta	Fruit	Sp gr = 1.025-1.055	Caryophyllene, eugenol*,
164 officinalis)	(3.3-4.3)	α_D = 0 to -4	eugenol methyl ether, cineole
165 Jamaica		n_D = 1.5270-1.5400	
166 Pine, dwarf	Twigs,	Sp gr = 0.859-0.877	Pinene, limonene, dipentene,
167 (Pinus mugo)	leaves	α_D = -5 to -15.5	borneol, ketones, phenols
168 Austrian Tyrol	(0.3-0.6)	n_D = 1.4750-1.4800	

58	Clove	Dried, un-	Sp gr = 1.043-1.068	Caryophyllene, furfural,	169	Rose	Flowers	Sp gr = 0.848-0.863[6]	Stearoptenes, l-citronallol*,
59	(Eugenia caryophyllata)	opened buds	α_n = to -1.58	eugenol*, vanillin, methyl	170	(Rosa damascena)	(0.02)	α_n = -1 to -4	geranial, l-linalool, nerol,
60	Madagascar, Zanzibar	(15,5-17)	n_n = 1.5270-1.5350	salicylate and benzoate	171	Bulgaria, Turkey		n_n = 1.4570-1.4630[6]	phenylethyl alcohol
61	Coriander	Seeds	Sp gr = 0,870-0,885	Linalool*, p-cymene, l-borneol,	172	Rosemary	Entire	Sp gr = 0.901-0.919	a-Pinene, borneol, camphor,
62	(Coriandrum sativum)	(0.15-1.1)	α_n = +4 to +13	geranial, n-decylaldehyde, acetic	173	(Rosmarinus officinalis)	plant	α_n = -5 to +10	bornyl acetate, cineole
63	Europe		n_n = 1.463-1.471	acid, decylic acid	174	Mediterranean	(0.4-0.7)	n_n = 1.4640-1.4760	
64	Cubeb	Berries	Sp gr = 0,909-0,930	Cubeb camphor, terpenes	175	Sage, Dalmatian	Leaves	Sp gr = 0.909-0.931	d-a- Pinene, salvene ($C_{10}H_{18}$),
65	(Piper cubeba)	(10-20)	α_n = -12,5 to +6		176	(Salvia officinalis)	(0,7-2,0)	α_n = +2 to +9	borneol, d- camphor, d-β-
66	Java, Singapore		n_n = 1.4919-1.4981		177	Mediterranean		n_n = 1.458-1.4690	thujone*, l-a-thujone*, cineole
67	Dill weed (Anethum	Entire	Sp gr = 0,890-0,906	a-Pinene, terpinene, carvone,	178	Sandalwood	Wood	Den. = 0.969-0.976[7]	a-Santalol*
68	graveolens) Europe,	plant	α_n = +84 to +95	d-phellandrene*, limonene	179	(Eucarya spicata)	(1.4-2.6)	α_n = -3 to -10	
69	North America, Hungary	(0,3-1,5)	n_n = 1.4800-1.4900		180	Australia		n_n = 1.498-1.508	
70	Estragon (Artemisia	Shoots	Sp gr = 0,900-0,956(?)	Phellandrene (?), p-methoxycin-	181	Sandalwood	Wood,	Sp gr = 0.965-0.980	Santene, a-santalol*, β-santalol*,
71	dracunculus) U.S.A.,	(0,35)	α_n = +1,9 to +9(?)	namaldehyde, methyl chavicol*	182	(Santalum album)	roots	α_n = -15 to -20	santalone, santalic acid, α- and β-
72	Southern France		n_n = 1.504-1.520(?)		183	Southern India	(4,5-6,2)	n_n = 1.500-1.5100	santalenes
73	Eucalyptus	Leaves	Sp gr = 0,922-0,930	p-Cymene, 1, 8-cineole*	184	Sassafras	Roots	Sp gr = 1.072-1.084	Phellandrene, a-pinene,
74	(Eucalyptus polybracteа)	(1,5-2,5)	α_n = +0,5 to +2		185	(Sassafras albidum)	(1.8)	α_n = +2 to +4	d- camphor, safrole*,
75	Australia		n_n = 1.458-1.462		186	U.S.A.		n_n = 1.528-1.5350	eugenol*
76	Fennel, bitter (Foeniculum	Seeds	Sp gr = 0,959-0,980	Camphene, d-a-phellandrene,	187	Spearmint	Entire	Sp gr = 0.923-0.940	l- Phellandrene, dihydrocarveol ,
77	vulgare) France,	(1-6)	α_n = +12 to +24	anisaldehyde, d-fenchone,	188	(Mentha spicata)	plant	α_n = +48 to +59	l- carvone*, (l- linalool*,
78	Italy, India, Russia		n_n = 1.528-1.5380	anethole*, methyl chavicol	189	North America	(0,7)	n_n = 1.4840-1.4910	cineole in Russian variety).
79	Geranium (Pelargonium	Shoots	Sp gr = 0,889-0,904	l-a- Pinene, sesquiterpenes, citro-	190	Spruce	Leaves	Sp gr = 0.874-0.888	a-Pinene, β-pinene, bornyl
80	app) Algeria, Réunion	(0,15)	α_n = -7 to -14	nellal*, sesquiterpene alcohols,	191	(Picea excelsa)	(0,2)	α_n = -20,6 to -40	acetate, dipentene cadinene
81			n_n = 1.4629-1.4720	l-isomenthone, formic esters	192	Norway		n_n = 1.474-1.478	
82	Ginger (Zingiber	Dried	Sp gr = 0,877-0,888	d- Camphene, d-β-phellandrene,	193	Tangerine	Fruit	Sp gr = 0.850-0.856	Limonene*
83	officinale) Asia,	rhizomes	α_n = -28 to -45	d- borneol, singeberol, citral,	194	(Citrus reticulata)	(0,1)	α_n = +90,7 to +93,5	
84	West indies, Africa	(1,5-3,0)	n_n = 1.4880-1.4940	cineole, zingiberene	195	Java, W. Indies, Florida		n_n = 1.4732-1.4750	
85	Gingergrass	Grass	Sp gr = 0,900-0,953	Geraniol*	196	Tansy	Herba	Sp gr = 0.916-0.9409	β- Thujone*
86	(Cymbopogon martini	(1-1,25)	α_n = +54 to -30		197	(Tanacetum vulgare)	(0,2-0,5)	α_n = -6,3 to +38,8	
87	var. sofia) India		n_n = 1.4780-1.4930		198	England, France, U.S.A.		n_n = 1.4456-1.4707	
88	Grapefruit	Peel	Sp gr = 0,855-0,860	Limonene*, linalool, citral,	199	Thyme	Flowering	Sp gr = 0.916-0.941	Camphene, caryophyllene,
89	(Citrus paradisi)	(0.06)[4]	α_n = +91 to +96[5]	decylaldehyde, octylaldehyde,	200	(Thymus vulgaris)	plant	α_n = -0,27 to -3,2	β-pinene, l-borneol,
90	U.S.A., Brazil		n_n = 1.4750-1.4780	umbelliferone	201	Spain	(0,7-2,6)	n_n = 1.495-1.505	carvacrol, thymol*
91	Guaiac wood	Wood	Sp gr = 0,973-0,985	Guaid, bulnesol	202	Tuberose	Flowers	Sp gr = 1.000-1.035	Methyl salicylate and anthranilate,
92	(Guaiacum officinale)	(2,7-5,4)	α_n = +3 to +12,3		203	(Polyanthes tuberosa)	(0,08)	α_n = -2,5	methyl and benzyl benzoates
93	Argentina, Paraguay		n_n = 1.502-1.508		204	France		n_n = 1.5136-1.5352	
94	Hyssop	Leaves,	Sp gr = 0,9237-0,936	l- Pinocamphone*	205	Turpentine gum, American	Oleoresin	Sp gr = 0.8630-0.874	d-a- Pinene*, l-β-pinene,
95	(Hyssopus officinalis)	blossoms	α_n = -15,7 to -19,3		206	(Pinus palustris)	(20)	α_n = +15(?)	terpinolene, pinocarveol,
96	Mediterranean region, France	(0,15-0,8)	n_n = 1.4783-1.4829		207	U.S.A.		n_n = 1.4680-1.4780	methyl chavicol
97	Jasmine	Flowers	Sp gr = 0,953-1.047	Benzyl Acetate*, l- linalool	208	Vetiver	Roots	Sp gr = 0.9352-1.058	Vetivenols*, α- and β- vetivones,
98	(Jasminum officinale)	(0.17)	α_n = +2,2 to +3,7		209	(Vetiveria zizanioides)	(1.5-2,0)	α_n = +14 to +45	benzoic and palmitic acids
99	India, Arabia, China		n_n = 1.4944-1.5015		210	India, Burma		n_n = 1.510-1.5306	
100	Juniper berry	Fruit	Sp gr = 0,860-0,879	a-Pinene, borneol(?), geraniol(?),	211	Wintergreen	Leaves	Sp gr = 1.184-1.190	Methyl salicylate*, an ester
101	(Juniperus communis)	(0.8-1.6)	α_n = 0 to -15	l-terpinen-4-ol(?)	212	(Gaultheria procumbens)	(0,5-0,7)	α_n = -0,4 to -1.5	($C_{14}H_{24}O_2$), triacontane
102	Central Europe		n_n = 1.4740-1.4840		213	North America		n_n = 1.5350-1.5380	
103	Lavender	Leaves,	Sp gr = 0,882-0,895	a-Pinene, d- borneol, geraniol,	214	Wormseed, American	Dried	Den.=0.937-0.9908	Ascaridole*, p-cymene,
104	(Lavandula officinalis)	flowers	α_n = -3 to -10	lavandulol, l- linalool, l- linalyl	215	(Chenopodium ambrosioides)	plant	α_n = -0,1 to -12.5	l- limonene, a-terpinene,
105	France	(0,3-0,9)	n_n = 1.4590-1.4700	acetate*, coumarin	216	C.America, W.indies, U.S.A.	(1-2)	n_n = 1.4741-1.4778	d-camphor, butyric acid
106	Lavandin	Leaves,	Sp gr = 0,884-0,897	Linalool*, linalyl acetate*,	217	Wormwood	Shoots	Sp gr = 0.884-0.9547(?)	An azulene, phellandrene,
107	(Lavandula hybrida)	flowers	α_n = -2 to -6	d- borneol, d- camphor,	218	(Artemisia absinthium)	(0,3-0,4)	α_n = (?)	thujyl alcohol, a-thujone*,
108	Southern France	(1-1,8)	n_n = 1.4610-1.4650	d- camphene, cineole	219	Europe, North America		n_n = 1.460-1.483(?)	β-thujone, thujyl acetate
109	Lemon	Fruit	Sp gr = 0,849-0,8555	d- Limonene*, geraniol, linalool,	220	Ylang ylang (Cananglium	Flowers	Sp gr = 0.956-0.991	d- Caryophyllene, d-a-pinene,
110	(Citrus limon)	rind	α_n = +57 to +65,6[5]	citral*, cadinene, bisabolene	221	odoratum) Philippines,	(1,8-2,6)	α_n = -23 to -43	benzyl alcohol, acetate and
111	Italy, Spain, U.S.A.	(0,3-0,6)[4]	n_n = 1.4738-1.4755		222	Java, and other areas		n_n = 1.4960-1.5050	benzoate, methyl benzoate*

/1/ Plant from which oil is obtained, followed in parentheses by yield of oil, expressed as g per 100 g plant material. /2/ Sp gr = specific gravity; den. = density; α_n = optical rotation; n_n = refractive index. Values for specific gravity are calculated to $\frac{15°C}{15°C}$; those for n_n are reported at $\frac{20°C}{20°C}$ /3/ For most of the oils listed these constituents are only a few of those that have been identified. An asterisk immediately following a constituent indicates that constituent is present in the greatest amount and/or most important organoleptically or for commercial uses. /4/ Method of production is by expression of specified material. /5/ Determined at 25°C. /6/ Determined at 30°C. /7/ Calculated to $\frac{15°C}{15°C}$. /8/ Determined at 25°C and referred to water at the same temperature.

31. NATURAL TEXTILE FIBERS: PHYSICAL AND CHEMICAL CHARACTERISTICS

	Fiber	Specific Gravity	Fiber Length cm	Fiber Diameter μ	Tensile Strength kg/sq mm	Tenacity g/Grex[1]	Ultimate Elongation %	Young's Modulus dynes/sq cm[2]	Initial Young's Modulus g/den[1]	Stiffness g/Grex[1]	Density g/cu cm
1	Abaca (Musa textilis)	1.48-1.50	150-350	14-35	40,7	5.0	2.2-3.8			175	1.50
2	Banana (M. paradisiaca sapientum										
3	Cotton, Egyptian (Gossypium peruvianum)	1.54	3.6	16.4	44	3.8	7		74		1.55
4	Cotton, Sea Island (G. barbadense)	1.54	2.8-3.6	9.5	68	5.3	7		33-36		1.55
5	Cotton, Upland (G. hirsutum)	1.54	0.6-6.25	18	37-76	2.0-5.0	7	5.9	49-54	57	1.55
6	Coir (Cocos nucifera)		21	18							
7	Flax (Linum usitatissimum)	1.50	15.2-92	15	76	5.5	1.6	36		270	1.50
8	Green hemp (Crotalaria temulfolia)										
9	Hemp (Cannabis sativa)	1.49	92-183	18-23	84	4.0	3-5	5.1		200	1.50
10	Henequen (Agave fourcroydes)		75-112	17.6-17.9		3.0	3.5-4.5				
11	Jute (Chorchorus sp)	1.49	150-360	15,5	41	2.8	0.8	4.5-13.8		185	1.50
12	Kenaf (Hibiscus cannabinus)		165	24	22						
13	Mauritius hemp (Fourcroea gigantea)										
14	Musk-dana (Hibiscus abelmoschus)										
15	Ramie (Boehmeria nivea)	1.52	20-30	25.5	91-99	5.0	3.7			167	1.53
16	Roselle (Hibiscus sabdariffa)										
17	Sansaveria (Sanseveria sp)			20	23.3		2.7				
18	Sisal (Agave sisalana)		45-90	10-30	40	5.0	2.0-2.5			127	0.317
19	Sunn (Crotalaria juncea)			31							
20	Urena (Urena lobata)										
21	Silk, boiled	1.25	Continuous	5-21	45,5	3.4	13-20	6,9-8.8	1.6	15	1.35
22	Wool, scoured[5]	1.30	3.75-38	25	17.2	1.3	30-50	2.5-3.9	0.5	4	1.30

	Fiber	Specific Heat	Moisture Regain[3] %	Cellulose g/100g[4]	Holocellulose g/100g[4]	α-Cellulose g/100g[4]	Furfural Yield g/100g[4]	Lignin g/100g[4]	Fat and Wax g/100g[4]	Water Extractables g/100g[4]	Ash g/100g[4]
1	Abaca (Musa textilis)	0.322		63-86			9	8.6	0.71	1.09	1.15
2	Banana (M. paradisiaca sapientum)				85	58	9.37	13.06			2.63
3	Cotton, Egyptian (Gossypium peruvianum)	0.319	7.0-8.5	90							
4	Cotton, Sea Island (G. barbadense)	0.319	7.0-8.5	90							
5	Cotton, Upland (G. hirsutum)	0.319	7.0-8.5	88-95					0.7	2.66	1.32
6	Coir (Cocos nucifera)			61				33			
7	Flax (Linum usitatissimum)	0.322	12	45-80	90	59	1.46	4.53	2.6	6.75	0.79
8	Green hemp (Crotalaria temulfolia)				91	58	1.47	5.46			1.39
9	Hemp (Cannabis sativa)	0.323	12	59-85					0.62	3.82	0.90
10	Henequen (Agave fourcroydes)		4.6	48-88				5.4			1.1
11	Jute (Chorchorus sp)	0.324	13.8	51-88	83	61	6.64	11.78	0.82	1.14	0.50-1.56
12	Kenaf (Hibiscus cannabinus)		9.8	82		61-64		7.43-8.47			0.60-1.34
13	Mauritius hemp (Fourcroea gigantea)			81				18			2.0
14	Musk-dana (Hibiscus abelmoschus)				80	49	11.04	9.81			0.84
15	Ramie (Boehmeria nivea)		12	72-97	97	89	1.29	0.08		2.4	1.2
16	Roselle (Hibiscus sabdariffa)				84	54	9.61	6.88			0.61
17	Sansaveria (Sanseveria sp)			88	85	60	10.94	7.30		2.3-2.5	0.7-0.8
18	Sisal (Agave sisalana)		6.2	53-80	92	65	12.20	6.27			0.62
19	Sunn (Crotalaria juncea)		9.2	88	91	66	1.76	3.86	0.61	2.12	0.82
20	Urena (Urena lobata)			80	79	54	11.19	10.03			0.25
21	Silk, boiled	0.331	10.3-12.4								
22	Wool, scoured[5]	0.326	14.7								

/1/ 1 Grex = 0,9 denier. 1 denier = wt in g per 9000 m fiber length. /2/ Values presented as dynes per sq cm x 10^{10}. /3/ Moisture regain at 65% relative humidity, 21°C. /4/ Dry weight. /5/ Contains keratin, 98 g/100g.

This table describes certain characteristics of the protoplasmic surface of some representative animal and plant cells. Values in parentheses are ranges and conform with estimate "d" of the 95% range (cf Introduction).

Part I: SURFACE TENSION

	Organism	Cell	Dynes/cm
1	Sea urchin (Arbacia punctulata)	Egg, unfertilized	0.2[1]
2	Sea urchin (A. punctulata)	Egg, fertilized	0.09[2]
3	Marine worm (Chaetopterus pergamentaceus)	Egg, unfertilized	1.3[1]
4	Salamander (Triturus viridescens)	Egg, unfertilized	0.16[3]
5	Salamander (T. viridescens)	Egg, fertilized	0.10(0.06-0.17)[3]
6	Marine mollusk (Busycon canaliculatum)	Egg, fertilized	0.34(0.13-0.66)[3]
7	Clam (Cumingia tellanoides)	Egg, unfertilized	0.54[1]
8	Mollusk (Illyanassa obsoleta)	Egg, fertilized	1.1[1]
9	Newt (Triturus pyrrhogaster)	Erythrocyte	1.4[4]
10	Frog (Rana pipiens)	Leukocyte	1.3[1]
11	Rabbit (Oryctolagus cuniculus)	Leukocyte (macrophage)	2.1[2]
12	Protozoa (Amoeba dubia)		(1-3)[1]
13	Slime mold (Physarum polycephalum)		(0.1-0.6)[1]

/1/ Centrifugal fragmentation technique. /2/ Kinetic (Poiseuille's Law) technique. /3/ Sessile drop technique. /4/ Force to stretch cell with needle.

Part II: THICKNESS OF PLASMA MEMBRANE

	Organism	Cell	Microns
1	Man (Homo sapiens)	Erythrocyte	(0.015-0.026)[1]
2	Man (H. sapiens)	Erythrocyte	0.5[2]
3	Dog (Canis familiaris)	Erythrocyte	0.003[3]
4	Mouse (Mus musculus)	Mitochondria of cell of kidney tubule	0.016[1]
5	Rabbit (Oryctolagus cuniculus)	Erythrocyte	0.012[3]
6	Rabbit (O. cuniculus)	Erythrocyte	(0.021-0.023)[4]
7	Rabbit (O. cuniculus)	Leukocyte	0.003[3]
8	Protozoa (Amoeba proteus)		0.05[1]
9	Bacteria (Bacillus cereus)		(0.21-0.35)[5]
10	Yeast (Saccharomyces sp)		0.004[3]

/1/ Electron microscope. /2/ Diffraction method (wet membrane). /3/ Dielectric method. Assumed dielectric constant of 3. /4/ Leptoscopic method (dry membrane), pH 6.0. /5/ Microscopic stain technique.

Part III: ELECTROKINETIC PROPERTIES OF CELL MEMBRANES

	Organism	Cell[1]	Zeta Potential mV	Electrophoretic Mobility μ/sec/V/cm
1	Sea urchin (Arbacia punctulata)	Egg, unfertilized[2]	30(26-36)	1.6(1.3-1.7)
2	Sea urchin (A. punctulata)	Egg, unfertilized[3]	34(30-39)	18(15-20)
3	Sea urchin (Pseudocentrotus depressus)	Egg, unfertilized[2]	25	
4	Starfish (Asterias forbesi)	Egg, unfertilized[2]	20	
5	Starfish (A. forbesi)	Egg, unfertilized[3]	19	
6	Marine clam (Cumingia tellenoides)	Egg, unfertilized[2]	29	
7	Marine clam (C. tellenoides)	Egg, unfertilized[3]	34(31-37)	
8	Man (Homo sapiens)	Erythrocyte	16.8	1.31[4]
9	Man (H. sapiens)	Leukocyte[5]		0.38(0.33-0.44)
10	Man (H. sapiens)	Lymphocyte[5]		0.51(0.47-0.56)
11	Cat (Felis catus)	Erythrocyte	17.8	1.39
12	Dog (Canis familiaris)	Erythrocyte	21.1	1.68
13	Guinea pig (Cavia porcellus)	Erythrocyte	14.2	1.11
14	Guinea pig (Cavia porcellus)	Leukocyte[6]	17.0	1.20
15	Horse (Equus caballus)	Erythrocyte[7]	26.0	0.98(0.90-1.07)
16	Horse (E. caballus)	Leukocyte[7]	14.5	0.54(0.46-0.59)
17	Horse (E. caballus)	Lymphocyte[7]	17.0	0.60
18	Horse (E. caballus)	Platelets[7]	12.0	0.45(0.40-0.51)
19	Monkey (Macaca mulatta)	Erythrocyte	17.0	1.33
20	Mouse (Mus musculus)	Erythrocyte	17.9	1.4
21	Opossum (Didelphis azarae)	Erythrocyte	13.7	1.07
22	Rabbit (Oryctolagus sp)	Erythrocyte	7.0	1.03(1.01-1.08)[4]
23	Rat (Rattus rattus)	Erythrocyte	18.6	1.45
24	Sloth (Bradypus griseus)	Erythrocyte	12.4	0.97
25	Swine (Sus scrofa)	Erythrocyte	12.5	0.98
26	Bacteria β-hemolytic streptococci	Cell		1.0[6]
27	Bacteria (Escherichia coli)	Cell	(34-42)[8]	0.64[9]

/1/ All blood cells suspended in M/15 phosphate buffer solution of pH 7.4, unless otherwise indicated. /2/ Jelly removed from cell. /3/ Jelly not removed from cell. /4/ Suspended in an isotonic phosphate-buffer-glucose solution, pH 7.2. /5/ Suspended in physiological salt solution, pH 7.4. /6/ Suspended in M/15 phosphate buffer, pH 7.0. /7/ Suspended in plasma or serum. /8/ Suspended in N/100 lactate buffer, pH 4.7. /9/ Suspended in M/15 phosphate buffer solution, pH 6.9.

Part IV: PERMEABILITY OF CELL SURFACES TO WATER

Values are cu μ per sq cm surface area per minute per atmosphere difference in osmotic pressure x 10^6, unless otherwise indicated. Experimental temperature, approximately 20° C.

	Animal	Value
	Protozoa	
1	Amoeba proteus	0.21[1]
2	Gregarina sp	20
3	Zoothamnium sp	(12-25)
	Eggs[2]	
4	Sea urchin (Arbacia punctulata)	10(9-13)
5	Sea urchin (A. punctulata)	14[3]
6	Sea urchin (Pseudocentrotus depressus)	21(18-24)
7	Starfish (Patiria miniata)	(10-40)
8	Sand dollar (Dendraster sp)	(10-40)
9	Marine clam (Cumingia tellenoides)	41(40-42)
10	Marine worm (Chaetopterus pergamentaceus)	(46-47)
11	Marine worm (Urechis caupo)	27
	Erythrocytes (except where indicated)	
12	Man (Homo sapiens)	360
13	Man (H. sapiens)	135[4]
14	Cattle (Bos taurus)	250
15	Rabbit (Oryctolagus cuniculus)	(35-1164)[5]
16	Rabbit (Oryctolagus cuniculus)	112[3, 4]
17	Rabbit (O. cuniculus)	29[4]
	Skeletal muscle	
18	Frog (Rana pipiens)	(118-666)[5]
	Plant	Value
19	Algae (Halicystis osterhoutii)	230(220-250)
20	Algae (Nitella flexilis)	4632[5]
21	Algae (Spirogyra sp)	3900[5]
22	Fern, water (Salvinia auriculata)	55
23	Onion (Allium cepa)	30

/1/ Unit is μ/sec. /2/ Unfertilized. /3/ Outward flow. /4/ Leukocytes. /5/ Unit is mol/sq cm surface area/min/g mol difference in concentration x 10^{-8}.

Part V: PERMEABILITY OF CELL SURFACES TO IONS

Values are cm per hr x 10^{-6}, unless otherwise indicated. Experimental temperatures: approximately 20° C for egg and muscle data, 37° for erythrocytes, 15° for nerve and all plants except Valonia which was 25° C.

	SODIUM	Value
	Animal	
	Eggs[1]	
1	Marine worm (Urechis caupo)	600[2]
	Erythrocytes	
2	Man (Homo sapiens)	(0.6–1.6)
3	Man (H. sapiens)	13, 8[11], 3–15, 8[3]
4	Cat (Felis catus)	5
5	Dog (Canis familiaris)	14
6	Frog (Rana pipiens)	2
	Skeletal muscle	
7	Frog (Rana pipiens)	400
8	Frog (R. pipiens)	0.07(0.05-0.08)[3, 4]
	Nerve	
9	Cuttlefish (Sepia officinalis)	10, 3[5], 3–15, 0)[5]
10	Cuttlefish (S. officinalis)	6, 6[4], 5–9, 6)[3, 5]
11	Cuttlefish (S. officinalis)	0.36(0.10-0.92)[6]
12	Squid (Loligo forbesi)	3, 5[2], 3–4, 1)[3]
13	Squid (L. pealei)	57, 600
	Plant	
14	Algae (Nitella coronata)	28, 8[2]
15	Algae (Tolypellopsis stelligera)	26(7–55)
16	Algae (Valonia macrophysa)	0, 09[2]
17	Algae (Valonia ventricosa)	0, 01[2]
18	Water plant (Elodea sp)	28, 8[2]

	POTASSIUM	Value
	Animal	
	Eggs[1]	
19	Starfish (Pisaster ochraceus)	600[2]
	Erythrocytes	
20	Man (Homo sapiens)	4, 8[4]
21	Cat (Felis catus)	2, 4[4]
22	Dog (Canis familiaris	5, 7
23	Frog (Rana pipiens)	8, 8[4]
	Skeletal muscle	
24	Frog (Rana pipiens)	3200
25	Rabbit (Oryctolagus cuniculus)	3200
26	Rat (Rattus rattus)	16, 000–50, 000
	Nerve	
27	Crab (Carcinus maenas)	0, 5[5]
28	Crab (C. maenas)	2, 9(2, 7–3, 6)[3, 5]
29	Crab (C. maenas)	0, 11[6]
30	Crab (C. maenas)	0.13(0.10-0.20)[3, 6]
31	Cuttlefish (Sepia officinalis)	0.39(0.32-0.47)[3]
32	Cuttlefish (S. officinalis)	4, 7(3, 9–5, 5)[3, 5]
33	Cuttlefish (S. officinalis)	0.10(0.06-0.22)[6]
34	Squid (Loligo pealii)	1250
	Plant	
35	Algae (Nitella clavata)	0, 01[2]
36	Algae (N. coronata)	157, 8[2]
37	Algae (N. flexilis)	0, 01[2]
38	Algae (Tolypellopsis stelligera)	28(10–48)
39	Algae (Valonia macrophysa)	0, 44[2]
40	Algae (V. ventricosa)	0, 05[2]
41	Water plant (Elodea sp)	157, 8[2]

	BROMINE	Value
42	Algae (Nitella coronata)	0, 0002[2]

	CHLORINE	Value
43	Algae (Valonia ventricosa)	0, 06[2]
44	Algae (Nitella coronata)	0, 0072[2]

	IODIDE	Value
45	Algae (Valonia macrophysa)	0, 0018[2]

	PO_4 (PHOSPHATE)	Value
46	Algae (Nitella coronata)	25[2]

	RUBIDIUM	Value
47	Starfish (Patiria miniata)	600[2]
48	Algae (Nitella coronata)	510[2]
49	Algae (Valonia ventricosa)	1, 12[2]

/1/ Unfertilized, /2/ Unit is mol/sq cm surface area/min/g mol difference in concentration x 10^{-8}, /3/ Outward flow, /4/ Unit is mol/sq cm/min x 10^{-12}, /5/ Unit is mol/sq cm/impulse x 10^{-12}, /6/ Unit is mol/sq cm/min x 10^{-8}.

Part VI: PERMEABILITY OF CELL SURFACES TO NON-ELECTROLYTES

Values are in mol per sq cm surface area per minute per g mol difference in concentration x 10^{-8}, unless otherwise indicated. Temperature range, 20–25° C.

	ETHYLENE GLYCOL	Value
	Animal	
	Protozoa	
1	Gregarina sp	40, 2
	Eggs[1]	
2	Sea urchin (Arbacia punctulata)	36(29–56)
3	Starfish (Asterias sp)	102(50–182)
4	Marine worm (Chaetopterus pergamentaceus)	143(140–153)
5	Marine clam (Cumingia tellenoides)	156(151–163)
	Erythrocytes	
6	Cattle (Bos taurus)	9, 6
7	Hedgehog (Erinaceus europaeus)	246
8	Worm (Phascolosoma gouldi)	7, 3
	Plant	
9	Algae (Ceramium diaphanum)	49, 8
10	Algae (Chara ceratophylla)	71, 6
11	Algae (Melosira sp)	22, 5
12	Algae (Pylaiella litoralis)	5, 8
13	Algae (Spirogyra sp)	6, 6
14	Bacteria (Beggiatoa mirabilis)	83, 4
15	Moss (Plagiothecium denticulatum)	2
16	Oyster plant (Rhoeo discolor)	10, 4
17	Turmeric (Curcuma rubricaulis)	6, 6

	DIETHYLENE GLYCOL	Value
	Animal	
	Eggs[1]	
18	Sea urchin (Arbacia punctulata)	26
	Erythrocytes	
19	Cattle (Bos taurus)	4, 5
20	Worm (Phascolosoma gouldi)	3, 7

	PROPYLENE GLYCOL	Value
21	Protozoa (Gregarina sp)	79, 2
	Eggs[1]	
22	Sea urchin (Arbacia punctulata)	77
	Erythrocytes	
23	Cattle (Bos taurus)	19, 8
24	Worm (Phascolosoma gouldi)	11, 7
	Plant	
25	Algae (Chara ceratophylla)	145

	GLYCEROL	Value
	Animal	
26	Protozoa (Gregarina sp)	1, 1
	Eggs[1]	
27	Sea urchin (Arbacia punctulata)	5
28	Marine worm (Chaetopterus pergamentaceus)	62(58–69)
	Erythrocytes	
29	Man (Homo sapiens)	9
30	Cattle (Bos taurus)	0, 11
31	Hedgehog (Erinaceus europaeus)	163
32	Worm (Phascolosoma gouldi)	<0, 004
	Plant	
33	Algae (Ceramium diaphanum)	1, 3
34	Algae (Chara ceratophylla)	1, 2
35	Algae (Melosira sp)	2
36	Algae (Pylaiella litoralis)	0, 1
37	Algae (Spirogyra sp)	0, 2
38	Bacteria (Bacterium paracoli)	3, 3
39	Bacteria (Beggiatoa mirabilis)	63, 6
40	Moss (Plagiothecium denticulatum)	0, 02
41	Maianthemum (Maianthemum sp)	9, 8[2]
42	Oyster plant (Rhoeo discolor)	0, 7
43	Turmeric (Curcuma rubricaulis)	0, 1

	ERYTHRITOL	Value
	Animal	
	Erythrocytes	
44	Cattle (Bos taurus)	<0, 003
45	Hedgehog (Marmota monax)	31, 7
	Plant	
46	Algae (Ceramium diaphanum)	0, 1
47	Algae (Chara ceratophylla)	0, 08
48	Algae (Melosira sp)	0, 8
49	Algae (Pylaiella litoralis)	0, 007
50	Algae (Spirogyra sp)	0, 02
51	Bacteria (Bacterium paracoli)	0, 3
52	Bacteria (Beggiatoa mirabilis)	50, 3
53	Moss (Plagiothecium denticulatum)	0, 004
54	Oyster plant (Rhoeo discolor)	0, 03
55	Turmeric (Curcuma rubricaulis)	0, 02

	SACCHAROSE	Value
	Plant	
56	Algae (Chara ceratophylla)	0, 05
57	Algae (Melosira sp)	0, 4
58	Bacteria (Beggiatoa mirabilis)	8, 1
59	Moss (Plagiothecium denticulatum)	0, 0005
60	Turmeric (Curcuma rubricaulis)	0, 0005

	ACETAMIDE	Value
	Animal	
	Eggs[1]	
61	Sea urchin (Arbacia punctulata)	(55–60)
	Erythrocytes	
62	Cattle (Bos taurus)	283
63	Worm (Phascolosoma gouldi)	15, 8
	Plant	
64	Algae (Chara ceratophylla)	90

/1/ Unfertilized. /2/ Unit is mol/min x 10^{-8}.

Part VI: PERMEABILITY OF CELL SURFACES TO NON-ELECTROLYTES (Concluded)

Values are in mol per sq cm surface area per minute per g mol difference in concentration x 10^{-8}, unless otherwise indicated. Temperature range, 20–25°C.

	ACETAMIDE (concluded)	Value
	Plant (concluded)	
65	Algae (Melosira sp)	28, 2
66	Algae (Pylaiella litoralis)	16, 8
67	Moss (Plagiothecium denticulatum)	4
68	Turmeric (Curcuma rubricaulis)	4, 8
	PROPIONAMIDE	Value
	Animal	
	Eggs[1]	
69	Sea urchin (Arbacia punctulata)	(134-150)
	Erythrocytes	
70	Cattle (Bos taurus)	114
71	Worm (Phascolosoma gouldi)	62, 3
	Plant	
72	Algae (Ceramium diaphanum)	168
73	Algae (Chara ceratophylla)	216
74	Algae (Melosira sp)	180
75	Algae (Pylaiella litoralis)	84
76	Algae (Spirogyra sp)	27
77	Moss (Plagiothecium denticulatum)	12
78	Oyster plant (Rhoeo discolor)	9, 6
79	Turmeric (Curcuma rubricaulis)	13, 2
	MALONAMIDE	Value
	Animal	
80	Protozoa (Gregarina sp)	15
	Plant	
81	Algae (Ceramium diaphanum)	1, 5
82	Algae (Chara ceratophylla)	0, 2
83	Algae (Melosira sp)	1, 1
84	Algae (Pylaiella litoralis)	0, 1
85	Algae (Spirogyra sp)	0, $\frac{1}{2}$
86	Bacteria (Bacterium paracoli)	1, 7
87	Bacteria (Beggiatoa mirabilis)	94, 8
88	Moss (Plagiothecium denticulatum)	0, 05
89	Maianthemum (Maianthemum sp)	5, 5[2]
90	Oyster plant (Rhoeo discolor)	0, 01
91	Turmeric (Curcuma rubricaulis)	0, 02

	UREA	Value
	Animal	
	Erythrocytes	
92	Man (Homo sapiens)	1166
93	Cattle (Bos taurus)	1080
94	Hedgehog (Erinaceus europaeus)	1666
95	Worm (Phascolosoma gouldi)	1, 6
	Plant	
96	Algae (Ceramium diaphanum)	5
97	Algae (Chara ceratophylla)	6, 7
98	Algae (Melosira sp)	2, 5
99	Algae (Pylaiella litoralis)	0, 5
100	Algae (Spirogyra sp)	1, 1
101	Bacteria (Bacterium paracoli)	5
102	Bacteria (Beggiatoa mirabilis)	70, 2
103	Moss (Plagiothecium denticulatum)	0, 2
104	Maianthemum (Maianthemum sp)	(23, 4-33, 3)[2]
105	Oyster plant (Rhoeo discolor)	0, 2
106	Turmeric (Curcuma rubricaulis)	0, 09
	METHYL UREA	Value
	Plant	
107	Algae (Ceramium diaphanum)	5, 8
108	Algae (Chara ceratophylla)	11, 4
109	Algae (Melosira sp)	7, 2
110	Algae (Pylaiella litoralis)	1, 9
111	Algae (Spirogyra sp)	1, 7
112	Moss (Plagiothecium denticulatum)	0, 7
113	Maianthemum (Maianthemum sp)	75[2]
114	Oyster plant (Rhoeo discolor)	0, 5
115	Turmeric (Curcuma rubricaulis)	0, 5
	THIOUREA	Value
	Animal	
	Erythrocytes	
116	Cattle (Bos taurus)	1, 2
117	Hedgehog (Erinaceus europaeus)	138
118	Worm (Phascolosoma gouldi)	2
	Plant	
119	Algae (Chara ceratophylla)	12, 8
120	Maianthemum (Maianthemum sp)	90[2]
121	Oyster plant (Rhoeo discolor)	21[2]
	MANNITOL	Value
	Animal	
	Erythrocytes	
122	Man (Homo sapiens)	<0, 33
123	Cattle (Bos taurus)[3]	<0, 003
124	Hedgehog (Erinaceus europaeus)[4]	2
	Plant	
125	Algae (Chara ceratophylla)	<0, 05
	BUTYRAMIDE	Value
	Animal	
	Eggs[1]	
126	Sea urchin (Arbacia punctulata)	(338-394)
	Erythrocytes	
127	Cattle (Bos taurus)	163
128	Worm (Phascolosoma gouldi)[5]	410
	MONACETIN	Value
	Animal	
	Erythrocytes	
129	Cattle (Bos taurus)	6, 8
130	Worm (Phascolosoma gouldi)	0, 6
	Plant	
131	Algae (Chara ceratophylla)	26, 6
	DIACETIN	Value
	Animal	
	Erythrocytes	
132	Cattle (Bos taurus)	62, 5
133	Worm (Phascolosoma gouldi)	4, 5
	Plant	
134	Algae (Chara ceratophylla)	133
	TRIMETHYLENE GLYCOL	Value
	Animal	
	Eggs[6]	
135	Sea urchin (Arbacia punctulata)	43
	Erythrocytes	
136	Cattle (Bos taurus)	6
137	Worm (Phascolosoma gouldi)	7, 3

/1/ Unfertilized, /2/ Unit is mol/min x 10^{-8}. /3/ Triethylene glycol = 2; xylose = <0, 003; formamide = 293; propyl alcohol=636. /4/ Xylose = 0, 66. /5/ Formamide = 9, 8; tetraethylene glycol = 0. 4; triethylene glycol = 1, 2

Part VII: COMPOSITION OF ERYTHROCYTE STROMA

	Species	Protein	Lipid	Phospholipid	Cholesterol	Neutral Fat
		Per cent of Stroma				
1	Man (Homo sapiens)	49, 5	11, 2	7, 3	2, 6	1, 8
2	Cattle (Bos taurus)	57	25, 6	15, 9	7, 5	2, 0
3	Chicken (Gallus domesticus)	91	3, 9	2, 5	1, 1	0, 2
4	Horse (Equus caballus)	53	20, 4	12, 7	7, 4	0, 3
5	Sheep (Ovis aries)	68, 4	23, 9	14, 7	4, 9	4, 3

	Species	Histidine	Arginine	Lysine	Tyrosine	Tryptophan	Cysteine	Methionine
		Molecular Ratio in Stroma						
6	Man (Homo sapiens)	7	15	14, 5	8	3	2	3, 5
7	Cattle (Bos taurus)	6, 5	15	12	8	3	2	3
8	Horse (Equus caballus)	7	14, 5	13, 5	8	3	2	4
9	Sheep (Ovis aries)	8	14	11, 5	7	2, 5	2	4

	Species	Glycine	Leucine	Tyrosine	Tryptophan	Total Nitrogen	Amino Nitrogen
		Per cent Anhydrous Ash-free Stroma Protein					
10	Man (Homo sapiens)	3, 6	11, 2			15, 9	11, 6
11	Cattle (Bos taurus)	3, 7	10, 1	3, 4	1, 4	13, 7	10, 4
12	Sheep (Ovis aries)	3, 7	11, 4			15, 3	12, 0

	Species	Lipid	Cephalin	Lecithin	Cholesterol
		mg per sq m Stroma Surface Area x 10^{-12}			
13	Man (Homo sapiens)	4, 2			
14	Cat (Felis catus)	4, 4			
15	Cattle (Bos taurus)	3, 9	2, 3	0, 2	0, 6
16	Dog (Canis familiaria)	4, 9			
17	Monkey (Macaca mulatta)	4, 7	2, 0	1, 3	1, 3
18	Rabbit (Oryctolagus sp)	3, 9	1, 5	0, 4	1, 2
19	Rat (Rattus rattus)	4, 3	2, 4	0, 4	0, 8
20	Sheep (Ovis aries)	5, 6			

	Vitamin or Provitamin	Common Alternate Designations	Chemical Name	Molecular Formula	Units in Which Expressed	Physical State[1]	Melting or Boiling Point[1] °C	Stability[1]	Solubility[1, 2] g/100 ml	Specific Rotation[1] $[\alpha]_D^{t,\lambda}$	Absorption Maxima[4]
					Vitamins						
1	Vitamin A_1	Axerophthol; anti-xerophthalmia factor.	3,7-Dimethyl-9-(2, 6, 6-trimethyl-1-cyclohexen-1-yl)-2, 4, 6, 8-nonatetra-en-1-ol.	$C_{20}H_{30}O$	0.30 μg vitamin A alcohol, or 0.344 vitamin A acetate = one I.U. = one U.S.P. unit.	Pale yellow crystals.	62-64. Distills at 120-125 at $5x10^{-3}$ mm.	Inactivated by ultraviolet. Sensitive to air-oxidation.	s. most org. solv., fats, oils; i.w.	None.	325.5 in isopropanol.
2	Vitamin A_2			$C_{20}H_{28}O$		Yellow prisms.					351, 328
3	Vitamin A, neo-		5-cis-Vitamin A.	$C_{20}H_{30}O$		Yellow needles.	59-60				
4	Ascorbic acid	Vitamin C; anti-scorbutic factor.	L-Threo-2, 3, 4, 5-6-pentahydroxy-2-hexeno-γ-lactone.	$C_6H_8O_6$	0.05 mg = one I.U. or one U.S.P. unit.	Crystals, plates or needles; monoclinic, colorless.	190-192 with some decomposition.	Stable to air when dry. Impure preparations and natural products oxidised by air and light.	33 w. 3.5 al. 2 alba. al. 1 glyc.	$+20.5\text{-}21.5^{\frac{25}{D}}$ in w. $+48^{\frac{23}{D}}$ in me. al.	243.5 in metaphosphoric acid.
5	Biotin	Vitamin H; coenzyme R; factor S, W, X; bios II G; anti-egg white injury factor.	cis-Hexahydro-2-oxo-1H-thieno [3, 4] imidazole-4-valeric acid.	$C_{10}H_{16}N_2O_3S$	Gravimetric.	Fine, long needles or white crystalline powder.	232-233 (some decomposition).	Stable to air, temp. Moderately acid and neutral sol. stable several months; alk. sol. less stable.	0.022 w.$^{\frac{25}{}}$ 0.080 al.$^{\frac{25}{}}$ More s.b.w. or dil. alk.	$+91^{\frac{24}{D}}$ in 0.1 N NaOH.	
6	Choline		(β-Hydroxyethyl)trimethylammonium hydroxide.	$C_5H_{15}NO_2$	Gravimetric.	Colorless, viscous, hyg. alk. liquid.		Dil. aq. sol. stable to boiling; dec. hot alkali.	v.s.w., al.; i. eth.		
7	Cobalamin	Cyanocobalamin (vitamin B_{12}); hydroxycobalamin (vitamin B_{12a}, B_{12b}).	Not fully determined.	$C_{61-64}H_{86-92}N_{14}O_{13}PCo$	Gravimetric.	Hyg. dark red needles. Birefringent.	Darkens 210-220. Not melted 300.	Heat stable in aq. sol. Inactivated slowly by weak acid, alkali.	1.25 w.; s.al.; i.chl., acet., eth.	$-59^{\frac{23}{650}}$ a9 in dil. aq. sol.	548-550, 361, 278 in 0.1 N NaOH.
8	Vitamin D_2	Calciferol; activated ergosterol; anti-rachitic factor.	9, 10-Secoergosta-5, 7, 10(19), 22-tetraen-3-ol.	$C_{28}H_{44}O$	Crystals = 40 million I.U. or U.S.P. units per gram.	Prisms from acetone.	115-118 Sublimes in very high vacuum without decomposition.	Crystals stable 9 mo. in amber-evacuated ampuls at 4°C. Propylene glycol sol. stable in air for long periods of time.	6.95 acet.; s. most org. solv., sl. s. vegetable oils; i. w.	$+10^{\frac{25}{546.1}}$ in al. +82.6 in acet. +91.2 in eth. +52 in chl.	264.5a0.5 in ethanol or hexane.
9	Vitamin D_3	Activated 7-dehydrocholesterol.	22, 23-Dihydro-24-demethylcalciferol.	$C_{27}H_{44}O$	Crystals = 40 million I.C.U.[5] or I.U. per gram.		82-83		s. most fat solv.; i. w.	$+83.3^{\frac{20}{546.1}}$ in acet.	
10	Vitamin E	α-Tocopherol, anti-sterility factor.	5, 7, 8-Trimethyltocol.	$C_{29}H_{50}O_2$	One mg DL-α-tocopherol acetate = one I.U.	Slightly viscous pale-yellow oil.	Boils 200-220 at 0.1 mm.	Very stable to heat, a. Slowly oxidized by atmospheric O_2, rapidly by ferric and silver salts.	v.s. oils, fats, acet., chl., al., eth.; i.w.	$+0.32^{\frac{25}{546.1}}$ in al. -3.6 in bz.	292 in ethanol,
		β-Tocopherol[5].	5, 8-Dimethyltocol.	$C_{28}H_{48}O_2$		Yellow oil.		Same as α-	Same as α-	$+2.0^{\frac{25}{546.1}}$ in al.	295
		γ-Tocopherol[5].	7, 8-Dimethyltocol.	$C_{28}H_{48}O_2$		Crystals.		Same as α-	Same as α-	$+2.2^{\frac{25}{546.1}}$ in al.	295
		ε-Tocopherol[5].	8-Methyltocol.	$C_{27}H_{46}O_2$		Yellow oil.		Same as α-	Same as α-	$+3.2^{\frac{25}{546.1}}$ in al.	298
11	Inositol	meso-Inositol; i-inositol; bios I.	Hexahydroxycyclohexane.	$C_6H_{12}O_6$	Gravimetric.	Efflorescent crystals (dihydrate).	218 (dihydrate) 250-253 anh.	Becomes anhydrous at 100°. Decomposes at 250°C	17.5 w. i.abs.al., eth.	Inactive.	
12	Vitamin K_1	Antihemorrhagic vitamin; vitamin K^6	2-Methyl-3-phytyl-1, 4-naphthoquinone.	$C_{31}H_{46}O_2$	Gravimetric in terms of menadione.	Yellow, viscous oil.	-20. Dec. above 100-120.	Stable to air, moisture. Dec. sunlight.	i.w.; sl.s.me. al.; s.al., chl., bz., acet., eth.	$-0.4^{\frac{20}{(57.5\% \text{ in bz.})}}$	239, 243, 249, 260, 270,
13	Vitamin K_2		2-Methyl-3-difarnesyl-1, 4-napthoquinone.	$C_{41}H_{56}O_2$		Yellow crystals.	53.5-54.5	Stable dil.a.; labile alk. hydroxides.			325 in hexane.
14	Niacin	Nicotinic acid; P.P. factor.	Pyridine-3-carboxylic acid.	$C_6H_5NO_2$	Gravimetric.	Colorless needles.	236.5	Stable in air, and to light and pH. Non-hyg.	1.67 w.$^{\frac{25}{}}$ 0.73 al.$^{\frac{25}{}}$; i. eth.	Inactive.	213, 263, 212, 261 in hexane.

15	Niacinamide	Nicotinic acid amide.	Pyridine-3-carboxamide.	$C_6H_6N_2O$	Gravimetric	White cryst. powder.	129-131		100 w.; 66.6 al.;sl.s.eth.	Inactive.	
16	Pantothenic acid	Chick anti-dermatitis factor; factor H.	D(+)-N-(α, γ-Dihydroxy-β, β-dimethylbutyryl)-β'-alanine.	$C_9H_{17}NO_5$	One "chick unit" = 0.14 μg D-pantothenic acid.	Colorless, viscous oil.	Unstable. Ca salt dec. 195-196.	Very hyg. Labile to a., alk., heat. Ca salt stable to air and light.	v.s.w., glac. acet.,s.;sl.s. eth.,i.;i.bz., cbl.	$+37.5^{25}$ Ca salt: $+28.2^{25}$	
17	Para-amino-benzoic acid	PABA	p-Aminobenzoic acid.	$C_7H_7NO_2$	Gravimetric.	Mono-clinic prisms from dil. al.	187.0-187.5	Incompatible with ferric salts and oxidizing agents.	0.5 w.^{25};v.s. al., eth., glac. acet.s.,sl.s.bz.	Inactive.	264 in alk.; 225,270 in a.
18	Pteroyl-glutamic acid	PGA; folic acid; folacin, vitamin M; L. casei factor; vitamin B_c.	N-[4-[[(2-Amino-4-hydroxy-6-pteridyl)-methyl]-amino]-benzoyl]-L-glutamic acid.	$C_{19}H_{19}N_7O_6$		Yellowish-orange crystals.	Darkens and chars from about 250°.	Very labile to heat in a. media. Sunlight causes deterioration.	sl.s.w., me. al.,i.;acet., chl., eth., bz.;s.acet.a.		257, 282, 365 in 0.1 N NaOH.
19	Pyridoxine[7]	Vitamin B_6; HCl; anti-acrodynia factor; adermine.	5-Hydroxy-6-methyl-3, 4-pyridine dimethanol hydrochloride.	$C_8H_{11}NO_3 \cdot HCl$	Gravimetric.	White, odorless powder.	205-212 dec. Sublimes: free base 160.	Fairly stable to light and air. Acid sol. stable; may be heated 120° for 30 minutes.	22 w.; 1. 1 eth. al.;sl.s. acet.,i.eth.	Inactive.	291; 220, 254, 325; 245, 309.5[8]
20	Riboflavin	Vitamin B_2; vitamin G; lactoflavin; ovoflavin; hepatoflavin.	6,7-Dimethyl-9-(D-1'-ribityl)-isoalloxazine.	$C_{17}H_{20}N_4O_6$	Gravimetric	Yellow to orange-yellow polymorphic crystals.	277-291 with decomposition.	When dry, stable to diffused light. Very labile in alk. sol. especially in light. Stable to mineral acids in dark.	0.019^{40} w.; 0.0427.5 al.; i.eth., acet., chl., bz.	-112 to -122 in dil. alcoholic NaOH (50 mg in 2 ml).	223, 267, 375, 444 in 0.1 N HCl.
21	Thiamine	Vitamin B_1; aneurin anti-neuritic factor.	3-(4-Amino-2-methylpyrimidyl-5-methyl)-4-methyl-5-β-hydroxy-ethylthiazolium chloride hydrochloride[9].	$C_{12}H_{17}N_4OSCl \cdot HCl$	1 gram contains 330,000 I.U. pure thiamine-HCl.	Monoclinic plates in rosette clusters, or white powder.	246-250 dec.	When dry, stable at 100°. Very hyg. absorbing nearly one mole H_2O in air forming a hydrate.	100 w.; 1 al.; 0.3 abs.al.; 5 gly.;i.bz., eth., chl., benzace.	Inactive.	246; 263 in 0.1 N HCl.
					Provitamins						
22	β-Carotene[10]	Provitamin A.		$C_{40}H_{56}$	0.0006 mg = one I.U.	Red crystals.	180 corr.	Sensitive to O_2, autooxidation in light; stable to heat.	i.-w.;sl.s.al., eth.,s.bz., pet.eth., CS_2		520, 485 450 in CS_2.
23	Ergosterol	Provitamin D_2.	$\Delta^{5,7,22}$-Ergostatrien-3β-ol.	$C_{28}H_{44}O$		Small white plates from al.	168	Destroyed by UV; dec. oxid. agents.	v.s.most fat solv.,i.w.	-130 in chl.	280 in eth.
24	7-Dehydro-cholesterol	Provitamin D_3.	$\Delta^{5,7}$-Cholestadien-3β-ol.	$C_{27}H_{44}O$		Crystals.	150		v.s.most fat solv.,i.w.	-113 in chl.	280 in eth.
25	22-Dihydro-ergosterol	Provitamin D_4.		$C_{28}H_{46}O$		Crystals.	152-153		v.s.most fat solv.,i.w.	-109 in chl.	
26	7-Dehydro-sitosterol	Provitamin D_5.		$C_{29}H_{49}O$		Crystals.	144-145		v.s.most fat solv.,i.w.	-116 in chl.	260
27	7-Dehydro-stigmasterol	Provitamin D.		$C_{29}H_{46}O$		Crystals.	154		v.s.most fat solv.,i.w.	-113.1 in bz.	
28	Epi-7-dehydro-cholesterol	Provitamin D.		$C_{27}H_{44}O$		Crystals.	124-126		v.s.most fat solv.,i.w.	-70.5 in chl.	
29	Kitol	Dimer of vitamin A.		$C_{40}H_{60}O_2$		Prisms from al.	88-90		v.s.most fat solv.,i.w.	-1.35 in chl.	290
30	Lumisterol	Provitamin D_1[11].		$C_{28}H_{44}O$			118		v.s.most fat solv.,i.w.	+192 in acet.	
31	Panthenol	Provitamin(?) of pantothenic acid.	D(+)-3-(α, γ-dihydroxy-β-β-dimethyl butyrylamino)propanol.	$C_9H_{19}NO_4$	Gravimetric.	Colorless, viscous oil.	Racemizes at boiling point.	Labile to a., alk.	v.s.w., al.; sl.s.eth.	$+29.5^{20}$ (3% aq.)	
32	Tachysterol	Provitamin[11].		$C_{28}H_{44}O$					v.s.most fat solv.,i.w.	-70 in bz.	280

/1/ Abbreviations: a.=acid; abs.=absolute; acet.=acetone; glac. acet. a.=glacial acetic acid; al.=alcohol (95% ethyl); alk.=alkali; anh.=anhydrous; aq.=aqueous; bz.=benzene; chl.=chloroform; *corr.*=corrected; cryst.=crystals, crystalline; dec.=decomposes; dil.=dilute; eth.=ether; glyc.=glycerol; h.=hot; hyg.=hygroscopic; i.=insoluble; me.=methyl; org.=organic; oxid.=oxidizing; pet.=petroleum; s.=soluble; sl.=slightly; sol.=solution; solv.=solvents; UV=ultraviolet; v.=very; w.=water. /2/ Superscripts indicate temperature of solvent. /3/ Superscripts indicate temperature of measurement. /4/ International Chick Unit. /5/ Much less active than α-tocopherol. /6/ Synthetic vitamin K, menadione (2-methyl-1, 4-naphthoquinone), has similar activity as natural K. /7/ The vitamin B_6 group also includes pyridoxal and pyridoxamine, with different properties and biological activity. /8/ First value in 0.1 N HCl, next three in phosphate buffer at pH 7, and last two in 0.1 N NaOH. /9/ The mononitrate is a less hygroscopic form. /10/ Other carotenoids having vitamin A activity are α-carotene, γ-carotene, neo-β-carotene and cryptoxanthin. /11/ Intermediates between provitamin and vitamin.

34. MILK, CHEMICAL COMPOSITION: MAN, COW, GOAT

Ranges are given in parentheses, and represent estimate "c" of the 95% range (cf Introduction).

	Constituent per 100 ml Whole Milk	Man			Cow	Goat
		Colostrum[1]	Transitional Milk[2]	Mature Milk	Mature Milk	
1	Water, g	87(83-90)	86(84-90)	88(83-90)	87(80-92)	87(81-90)
2	Calories, utilizable[3]	57	64	65	65	68
3	Total solids, g	12.8(10-17)	13.6(10-16)	12.4(10-17)	12.7(8-20)	13.4(10-19)
4	Ash, g	0.33(0.2-0.7)	0.24(0.1-0.4)	0.21(0.1-0.5)	0.72(0.3-1.2)	0.77(0.4-1.1)
5	Protein, g	2.7(1-21)	1.6(1-3)	1.2(1-6)	3.3(2-6)	3.3(2-5)
6	Amino acids, total[4], g	1.20(0.7-4.0)	0.94(0.4-1.3)	1.28(0.9-1.6)	3.3(2.7-4.1)	
7	Casein, g	1.2(0.3-5.2)	0.7(0.4-1.8)	0.4(0.04-0.7)	2.8(1.4-6.3)	2.5(1.7-3.9)
8	Lactalbumin, g		0.8	0.3(0.1-0.6)	0.4(0.2-0.6)	0.4(0.4-0.6)
9	Lactoglobulin, g	3.5(0.4-13)	0.5(0.2-1.4)	0.2	0.2(0.1-0.4)	0.3
10	Whey protein, g	1.7		0.4(<0.3-1.1)	0.6(0.2-1.4)	1.1(0.8-2.0)
11	Carbohydrate, g	5.3(1.1-7.9)	6.6(4.8-8.4)	7.0(4.2-9.2)	4.8(2.1-6.1)	4.7(3.3-6.4)
12	Fat, g	2.9(0.7-12.7)	3.6(0.4-9.6)	3.8(0.5-9.0)	3.7(0.9-9.8)	4.1(1.2-8.4)
13	"Essential" fatty acids[5], mg	246		346	96	168
14	Vitamin A, estimated total[6], mcg	0.1(0.02-0.47)	0.1(0.06-0.2)	0.06(0.01-0.25)	0.04(0.015-0.95)	
15	Ascorbic acid, mg	4.4(0.4-10.4)	5.4(2.7-9.0)	4.3(0-11.2)	1.6(0.2-3.1)	1.4(Trace-3.2)
16	Biotin, µg	0.1(Trace-0.3)	0.4(Trace-1.8)	0.4(Trace-4.2)	3.5(0.2-11.0)	6.3(4.7-8.3)
17	Choline, mg			9(5-14)	13(4-28)	
18	Cobalamin[7], µg	0.04(0.01-0.15)	0.04(0-0.07)	Trace	0.56(0.07-1.15)	0.02(0-0.14)
19	Vitamin D, calc. as calciferol[8], µg			0.01(0-0.25)	0.06(0.01-0.1)	
20	Vitamin E, mg	1.3(0.1-4)	1.3(0.5-3)	0.6(0.1-1)	0.1	
21	Folic acid group[9], µg	0.05(0.01-0.15)	0.02(0.015-0.025)	0.2(0.1-0.36)	0.2(0.1-5)	0.03(0-0.16)
22	Inositol, mg			39(19-56)	13(3-39)	21(14-26)
23	Vitamin K, calc. as K_1[10], µg			2(0-17)	8(0-33)	
24	Niacin[11], µg	75(10-145)	175(60-360)	172(66-690)	85(19-150)	273(200-320)
25	Pantothenic acid, µg	183(29-302)	288(135-412)	196(80-584)	350(155-568)	289(130-338)
26	Para-aminobenzoic acid	(?)	(?)	(?)	(?)	(?)
27	Pyridoxine group[12], µg			11(2-22)	48(0-95)	7(4-13)
28	Riboflavin, µg	29.6(12-50)	33.2(27-49)	42.6(13-100)	157(20-342)	114(76-650)
29	Thiamine, µg	15(0.5-82)	6(0-26)	16(<1-43)	42(27-90)	48(32-68)
30	Calcium, mg	31(13-66)	94(18-53)	33(15-61)	125(56-381)	130(103-176)
31	Chlorine, mg	91(20-233)	54(17-116)	43(9-355)	103(70-290)	159(56-260)
32	Cobalt, µg				0.06	
33	Copper, mg	0.05(0.02-0.6)	0.05(0.04-0.07)	0.04(0.01-0.07)	0.03(0.003-0.40)	0.04(0.02-0.05)[13]
34	Fluorine, µg				16(7-28)	
35	Iodine, µg	12(4.5-45)	2	7(4-9)	21(0.4-187)	
36	Iron, mg	0.09(0.02->0.13)	0.04(0.02-0.05)	0.15(0.02-0.45)	0.10(0.01-1.0)	0.05(0.01-0.07)
37	Magnesium, mg	4(1-8)	4(2-5)	4(2-6)	12(7-22)	16(10-24)
38	Manganese, µg	Trace		0.7	2(<1-4)	8(7-9)
39	Phosphorus, mg	14(6-25)	17(10-32)	15(7-35)	96(56-129)	106(84-161)
40	Potassium, mg	74(66-87)	64(53-77)	55(27-81)	138(38-287)	181(106-242)
41	Silicon				Trace	
42	Sodium, mg	48(26-136)	29(19-54)	15(2-44)	58(31-214)	41(19-60)
43	Sulfur, mg	22(20-26)	20(15-23)	14(5-30)	30(24-44)	16(2-29)
44	Zinc, mg	0.62(0.07-0.98)	0.77(0.04->1.15)	0.53(0.02->1.38)	0.38(0.17-0.66)	Trace

/1/ 1st-5th day of lactation. /2/ 6th-10th day of lactation. /3/ Kilocalories, calculated on basis of "physiological fuel values" of 8.80 calories per gram of fat, 3.85 calories per gram of carbohydrate (lactose); and 4.25 calories per gram of protein. /4/ Represents only the total of values that are available. /5/ Arachidonic, octadecadienoic acid. /6/ Milligrams of carotenoids x 0.75 ÷ (0.6 x 4.3), plus mg preformed vitamin A = estimated total vitamin A. /7/ Vitamin B_{12}, cyanocobalamin. /8/ 0.025 µg calciferol = one I. U. /9/ Pteroylglutamic acid (folacin), vitamin M, vitamin B_c, factor U, L. casei factor, Norite eluate factor. /10/ 0.083 µg vitamin K_1 = one Dam unit. /11/ Nicotinic acid (niacin) and nicotinic acid amide (nicotinamide). /12/ Includes pyridoxine, pyridoxal, pyridoxamine. /13/ Range of means.

35. MILK, CHEMICAL COMPOSITION: VARIOUS ANIMALS

Values are grams per 100 grams whole milk.

	Animal	Water	Protein	Fat	Lactose	Ash		Animal	Water	Protein	Fat	Lactose	Ash
1	Antester	63	11	20	0.3	0.8	14	Horse	90.1	2.6	1.0	6.9	0.35
2	Bison	86.9	4.8	1.7	5.7	0.9	15	Llama	86.5	3.9	3.2	5.6	0.8
3	Buffalo	82.1	5.9	7.9	4.7	0.78	16	Monkey	88.4	2.2	2.7	6.4	0.18
4	Camel	87.7	3.5	3.4	4.8	0.71	17	Mule	90	2.0	1.8	5.5	0.47
5	Cat	81.6	10.1	6.3	4.4	0.75	18	Orangutan	88.5	1.4	3.5	6.0	0.24
6	Deer	65.9	10.4	19.7	2.6	1.4	19	Pig	82.8	7.1	5.1	3.7	1.1
7	Dog	76.3	9.3	9.5	3.0	1.2	20	Rabbit	71.3	12.3	13.1	1.9	2.3
8	Dolphin	44.9	10.6	34.9	0.9	0.53	21	Rat	72.5	9.2	12.6	3.3	1.4
9	Donkey	90.3	1.7	1.4	6.2	0.4	22	Reindeer	64.8	10.7	20.3	2.5	1.4
10	Elephant	70.7	3.6	17.6	5.6	0.63	23	Seal	46.4	9.7	42.0		0.85
11	Fox	81.6	6.6	5.9	4.9	0.93	24	Sheep	82.0	5.6	6.4	4.7	0.91
12	Guinea pig	81.9	7.4	7.2	2.7	0.85	25	Whale	44.8	11.1	21.2	1.6	1.7
13	Hippopotamus	90.4		4.5	4.4	0.1	26	Zebra	86.2	3.0	4.8	5.3	0.7

Values in parentheses are estimate "b" or "c" of the 95% range when so designated by superscript (cf Introduction).

Part I: GENERAL

	Property	Animal	Blood[1]	* Value,	Temp[2] °C	
1		Vertebrates	Whole	1.056(1.052-1.061)[b]	25/4	61
2		Man	RBC	1.093(1.089-1.097)[b]	25/4	62
3			Plasma	1.024(1.022-1.026)[b]	25/4	63
4		Cat	Whole	1.051(1.045-1.057)[b]		64
5		Cattle	Whole	1.052(1.046-1.058)[b]	20/4	65
6			RBC	1.084(1.079-1.090)[b]	20/4	66
7			Plasma	1.029(1.026-1.033)[b]	20/4	67
8		Dog	Whole	1.052		68
9		Goat	Whole	1.042(1.035-1.049)[b]	25/4	69
10			Plasma	1.022(1.019-1.025)[b]	25/4	70
11		Horse	Whole	1.053(1.046-1.059)[c]	20/4	71
12			Plasma	1.027(1.025-1.028)[c]	20/4	
13		Mouse	Whole	1.057(1.052-1.062)[b]	25/4	72
14		Rabbit	Whole	1.050(1.048-1.052)[b]	25/4	73
15			RBC	1.098(1.093-1.104)[b]		
16			Plasma	1.025(1.018-1.031)[b]		74
17	Specific gravity	Rat	Whole	1.054(1.046-1.061)[b]	25/4	75
18			Plasma	1.023(1.018-1.028)[b]	25/4	
19		Sheep	Whole	1.051(1.041-1.061)[c]	20/4	76
20			RBC	1.084(1.080-1.087)[c]		77
21			Plasma	1.028(1.025-1.029)[c]		78
22		Swine	Whole	1.046(1.039-1.054)[b]	25/4	
23			Plasma	1.022(1.019-1.025)[b]	25/4	79
24		Chicken	Whole	1.056(1.050-1.064)[b]		80
25			Plasma	1.019(1.017-1.021)[c]		81
		Invertebrates				82
26		Apis[3]	Whole	1.045		
27		Bombyx[3]	Whole	(1.032-1.041)		83
28		Calliphora[3]	Whole	1.021		84
29		Dellephila[3]	Whole	1.031		85
30		Dytiscus[3]	Whole	1.026		86
31		Gastrophilus[3]	Whole	1.062		87
32		Hydrophilus[4]	Whole	1.012		88
33		Periplaneta[4]	Whole	1.016		89
34		Phormia[3]	Whole	1.018		90
35		Prodenia[3]	Whole	1.032		91
		Vertebrates				92
36		Man	Whole	4.7	38	92
37			Plasma	1.8	38	93
38			Serum	1.5	38	94
39		Cat	Whole	4.2	38	95
40		Cattle	Whole	4.6	20	96
41		Dog	Whole	4.7	38	97
42		Goat	Whole	4.0	20	98
43			Whole	4.1	20	99
44		Horse	Plasma	1.9	20	
45			Serum	1.7	20	100
46		Rabbit	Whole	3.4	37	101
47	Relative viscosity[5]		Serum	1.4	37	102
48		Sheep	Whole	4.3	20	
49			Plasma	1.6	20	103
50			Serum	1.5	20	104
51		Swine	Whole	5.9	20	105
52			Serum	1.6	20	106
53		Chicken	Serum	1.4		107
54		Duck	Whole	4.0	20	108
55			Plasma	1.5	10-14	109
56		Goose	Whole	4.6	20	110
57			Plasma	1.5	12-17	111
58		Turtle	Whole	2.2	20	112
59		Frog	Whole	2.8	15	113
60			Serum	1.5	15	114

	Property	Animal	Value mm of water
		Mammals	
		Man	330(280-480)[c]
		Cat	300(240-330)[c]
		Cattle	280(260-300)[c]
		Dog	310(230-470)[c]
		Goat	300(300-310)[c]
		Guinea pig	250(230-280)[c]
		Horse	280(230-350)[c]
		Rabbit	290(230-350)[c]
		Rat	260(220-290)[c]
		Sheep	300(290-340)[c]
		Swine	330(300-350)[c]
		Birds	
		Chicken	150(140-160)[c]
		Dove	110(80-120)[c]
		Reptiles	
		Turtle (Malacoclemmys), spring	58(48-68)[c]
	Osmotic pressure, serum colloids	fall	96(80-110)[c]
		Amphibians	
		Frog (Rana catesbiana)	103(95-115)[c]
		Frog (R. temporaria)	70(to 140)[c]
		Toad (Bufo vulgaris)	133(85-240)[c]
		Fish, fresh-water	
		Carp, common (Cyprinus carpio)	(100-115)
		Eel (Anguilla anguilla)	225
		Pike (Esox lucius)	(110-145)
		Tench (Tinca vulgaris)	101(95-110)
		Fish, salt-water	
		Bass (Labrax lupus)	(175-250)
		Cod (Gadus morrhua)	113(112-114)
		Eel, conger (Conger conger)	(145-175)
		Dogfish, spiny (Squalus acanthias)	(42-43)
		Mackerel (Scomber scombrus)	(196-198)
		Plaice (Pleuronectes platessa)	115(105-125)
		Ray, electric (Torpedo marmorata)	(42-52)
		Scorpion fish (Scorpaena scrofa)	(180-185)
		Turbot (Rhombus maximus)	174

	Property	Animal	Value ΔT_f p °C
		Vertebrates	
		Man	0.562(0.555-0.570)[c]
		Cattle	0.585
		Dog	0.571
		Horse	0.564
	Freezing point depression, serum	Rabbit	0.592
		Sheep	0.619
		Swine	0.615
		Turtle	0.690
		Fish	
		Pike	0.514
		Plaice	0.732
		Tench	0.523
		Invertebrates	
		Aedes aegypti[3]	0.4-0.5
		Apis mellifera[3]	0.86
		Bombyx mori[3]	0.48
		Cancer spp	1.82
		Culex pipiens[3]	0.4-0.5
		Dytiscus circumcinctus[4]	0.56
	Freezing point depression, blood	Ephestia elutella[3]	1.12
		Melolontha vulgaris[3]	0.81
		Papilla japonica[3]	1.03
		Ranatra linearis[4]	0.75
		Saturnia pyri[3]	0.77
		Venus spp	1.39

Part II: RED BLOOD CELLS

	Property	Animal	Value milli-volts		Property	Animal	Value eq cm/volt sec x 10^{-4}		Property	Animal	Value[7] mm/hr		Property	Animal	Value[7] mm/hr
1		Man	-16.8	9		Man	1.31	17		Man ♂	(0-9)	25		Rabbit	2(1.5-2.5
2		Cat	-17.8	10		Cat	1.39	18		♀	(0-15)	26		Rat	(0.7-1.8)
3		Dog	-21.1	11		Dog	1.65	19		Cat	7.3(4-13)	27	Sedimen-	Sheep	0.5(0.5-0.7)
4	Electrical	Guinea pig	-14.2	12	Electro-	Guinea pig	1.11	20	Sedimen-	Cattle	1.2(1-1.8)	28	tation rate	Swine	5.3(3-8)
5	charge[6]	Monkey, rhesus	-17.0	13	phoretic	Monkey, rhesus	1.33	21	tation rate	Dog	4(2.5-5)	29	(concluded)	Chicken	3.7(2-6
6		Mouse	-17.9	14	mobility[6]	Mouse	1.40	22		Goat	0.5	30		Goose	3.4(2.7-4)
7		Rabbit	-7.0	15		Rabbit	0.55	23		Guinea pig	1.1(0.7-1.7)	31	Sedimen-	Man	(6-10 hours)
8		Rat	-18.6	16		Rat	1.45	24		Horse	1.25(1.20-1.35)	32	tation time	Rabbit	(17-42 hours)

/1/ RBC = red blood cells. /2/ For specific gravity, values are for the temperature of measurement referred to water at 4°C. /3/ Larva. /4/ Adult. /5/ Relative to water at temperature of measurement. /6/ M/15 phosphate buffer at pH 7.4. /7/ Measured at end of first hour.

Values are mg/100 ml (unless otherwise indicated) of blood or blood fraction shown in the column headings. Values in parentheses are ranges, and are estimate "d" of the 95% range unless followed by superscript (cf Introduction).

	Constituent	Whole Blood mg/100ml blood	Red Blood Cells mg/100ml RBC	Plasma mg/100ml plasma	Serum mg/100ml serum
1	Water, g/100ml	83(81-86)[1]	72(70-75)[2]	94(93-95)	93(93-94)[3]
2	Aluminum, μg/100ml	15(7-40)	7(7-17)	46(7-88)	
3	Bicarbonate, mEq/L	20.9(19.1-22.7)[3]			27(24-31)
4	Calcium, mEq/L	4.8	(0.6-1.4)	4.8(4.3-5.2)	5.2(4.8-6.1)
5	Chloride, mEq/L	82(71-87)	78	102(93-110)	102(97-108)[3]
6	Copper, μg/100ml	98(72-125)	115(71-160)	109(75-145)	
7	Fluoride, μg/100ml	28(11-45)	27(11-44)	28(10-45)	
8	Iodide, μg/100ml	7.7(3-13)			7.1(4.8-8.6)
9	Iodine, protein-bound, μg/100ml	(4.0-8.5)			5.0(3.6-6.4)
10	Iron	48(43-52)		0.1(0.03-0.18)	(0.08-0.15)
11	Lead, μg/100ml	29(18-49)	57(29-86)	2.9(7-7.8)	
12	Lithium, μg/100ml	1.9			
13	Magnesium, mEq/L	3.2(3.0-3.7)	5.1(1.6-6.6)		1.8(1.7-1.9)
14	Manganese, μg/100ml	130(-25)	19(7-48)	8(7-19)	
15	Phosphorus, acid-soluble	23.1(18.6-29)	50(39-59)	23(19-29)	5,1[3]
16	Potassium, mEq/L	48(39-62)	95(89-101)[3]	3.6	4.2(3.6-4.8)[3]
17	Silicon, μg/100ml	235(140-295)[4]			350(220-570)
18	Sodium, mEq/L	83(72-91)	18.6(8.7-28.6)[3]	(140-155)	138(132-144)[3]
19	Sulfate, mEq/L			(1.0-1.5)	
20	Tin, μg/100ml	22(7-40)	26(7-64)	4(7-10)	
21	Zinc, μg/100ml	880(490-1270)	1440(910-1970)	300(0-615)	125
22	Protein, total, g/100ml	(19.8-23.8)	36.8	(6.5-7.4)	(5.9-7.2)
23	Albumin, g/100ml			4.4(4.0-4.8)[3]	4.3
24	Globulin, g/100ml			2.5(1.8-3.3)[3]	2.9
25	Albumin-globulin ratio			1.7(1.3-2.2)[3]	1.5
26	α-Globulin, g/100ml			0.29(0.2-0.4)[3]	
27	α2-Globulin, g/100ml			0.56(0.4-0.7)[3]	
28	β-Globulin, g/100ml			0.84(0.6-1.1)[3]	1.01
29	γ-Globulin, g/100ml			0.90(0.6-1.2)[3]	0.93
30	Hemoglobin, g/100ml	(14.0-16.1)	33.5(30-40)[5]	Trace	
31	Fibrinogen, g/100ml	0.16		0.29	
32	Glycoprotein, acid			50	
33	Mucoprotein				(101-110)
34	Fructose	(0.5-5)			
35	Glucose	90(80-100)[6]	74(46-102)		97(61-130)[3]
36	Glycogen	5.5(1.2-16.2)[5]	0	0	0
37	Glucosamine	(60-82)			67(61-78)
38	Mucopolysaccharides			200	
39	Lipid, total	560(400-720)	600(410-780)[5]	530(385-675)[5]	
40	Fat, neutral	135(85-235)[5]	93(11-150)[5]	140(24-260)[5]	245(175-325)
41	Fatty acids			315(295-340)	
42	Phospholipid	245(185-310)	350(280-420)[5]	165(110-220)[5]	211(180-255)
43	Cephalin	65	210	(7-9)	
44	Lecithin	115	70	(117-156)	107
45	Sphingomyelin	185	70	(41-56)	
46	Cholesterol, total	(120-210)	175	(195-230)	(130-225)
47	Cholesterol esters			146	(121-125)
48	Ammonia	0.18(0.12-0.24)			(0.2-1.1)
49	Bilirubin	0.18(0.1-0.25)			

	Constituent	Whole Blood mg/100ml blood	Red Blood Cells mg/100ml RBC	Plasma mg/100ml plasma	Serum mg/100ml serum
50	Creatine	3.9(2.9-4.9)[3]	8.1(6.0-10.2)[3]		(2.5-3.0)
51	Creatinine	0.86	1.8(1.7-1.9)[3]	0.9(0.87-0.95)[3]	(0.7-1.1)
52	Glutamine			(4.6-10.6)	
53	Glutathione	34			
54	Histamine, μg/100ml	(6.7-8.6)			
55	Nucleotides	41(31-52)			
56	Purines, total	10.5			
57	Ribonucleic acid	64(48-79)	135(100-170)	4.9(3.9-5.9)	
58	Urea	(30-45)	30(25-39)[3]	34(28-40)[3]	(38-54)
59	Uric acid	3.2(2.2-4.2)[3]	1.9(0.8-3.0)[3]	3.8(2.0-5.6)[3]	(4.0-4.8)
60	Amino acids, total	50(38-53)			
61	Alanine	4.0(2.8-5.2)[3]	4.0(2.5-5.6)[3]	(2.4-7.6)	
62	Arginine	1.0(0.6-1.7)[3]	0.3(0.1-0.6)[3]	(1.2-3.0)	
63	Aspartic acid			(0-1.2)	
64	Cystine	0.9(0.6-1.2)[3]	0.4(0.3-0.5)[3]	(1.8-5.0)	
65	Glutamic acid			(0-1.3)	
66	Glycine	(1.8-2.5)	2.4(1.6-3.1)[3]	(0.8-5.4)	
67	Histidine	1.3(0.9-1.7)	1.1(0.8-1.6)	(1.0-3.8)	
68	Isoleucine	1.3(0.9-1.5)	0.9(0.5-1.4)	(1.2-4.2)	
69	Leucine	1.7(1.4-2.0)[3]	1.5(1.0-1.8)[3]	(1.0-5.2)	
70	Lysine	2.2(1.3-3.0)[3]	1.4(0.9-1.8)[3]	(2.3-5.8)	
71	Methionine	0.5(0.4-0.6)[3]	0.5(0.3-0.8)[3]	(0.25-1.0)	
72	Phenylalanine	1.0(0.8-1.2)[3]	1.0(0.7-1.3)[3]	(1.1-4.0)	
73	Proline			(1.5-5.7)	
74	Serine			(0.3-2.0)	
75	Tyrosine	1.6(1.3-2.0)[3]	1.6(1.3-2.1)[3]	(0.5-3.6)	
76	Tryptophan	0.7(0.5-1.0)[3]	0.24(0.2-0.4)[3]	(0.9-3.0)	
77	Tyrosine	1.1(0.8-1.4)[3]	1.1(0.7-1.5)[3]	(0.9-2.4)	
78	Valine	2.4(2.0-2.9)[3]	2.0(1.6-2.5)[3]	(2.5-4.4)	
79	Ergothioneine	(?-20)			
80	Adenosine triphosphate	(43-53)	(5.9-7.7) mg P		
81	Phosphoric acid ester	17.3			
82	Lactic acid	19(0-41)	12	36	
83	Vitamin A[7], μg/100ml	120(20-300)		220(40-540)	
84	Ascorbic acid	0.52(0.2-0.7)	1.0(0.5-2.8)	0.7(0.1-2.5)	
85	Biotin, μg/100ml	1.2(0.8-1.7)		1.3(1.0-1.7)	
86	Cobalamin, μg/100ml	0.08(0.06-0.14)			
87	Choline, total			(26-35)	
88	Choline, free	2.5(1.0-4.0)	(4.4-7.5)	(0.05-2.5)	
89	Vitamin D[8], μg/100ml				2.8(1.7-4.1)
90	Vitamin E			1.2(0.9-1.9)	
91	Folic acid, μg/100ml	3.5(2.3-5.3)		1.7(1.5-5.0)	
92	Inositol			0.5(0.4-0.8)	
93	Nicotinic acid	0.6(0.2-0.9)	1.3	0.07(0.02-0.15)	
94	Pantothenic acid μg/100ml	30(15-45)	25(15-30)	15(6-35)	
95	Para-aminobenzoic acid, μg/100ml	3.4			
96	Riboflavin, μg/100ml	(15-60)	22(18-26)	3.2(2.6-3.7)	
97	Thiamine, μg/100ml	8.0(4-11)	8(7-10)	7(1-9)	

/1/ A range of 80.5-80.8 has been reported. /2/ A value of 66 has been reported. /3/ Inorganic phosphorus. /4/ A value of 830 has been reported. /5/ All localized in granulocytes. /6/ A value of 315 has been reported. /7/ As β-carotene; 0.6 μg = one I. U. /8/ As calciferol; 0.025 μg = one I. U.

38. BLOOD, CHEMICAL COMPOSITION: VERTEBRATES OTHER THAN MAN

Values are mg/100 ml unless otherwise indicated, and are for plasma except where accompanied by the following code: Bl = blood; Ce = cells; S = serum. Values in parentheses are ranges and, unless followed by superscript, are estimate "df" of the 95% range (cf Introduction).

	Constituent	Cattle	Dog	Goat	Guinea Pig	Horse	Monkey	Rabbit
1	Water, g/100 ml	85 Bl	84 Bl	81 Bl		81 Bl		86 Bl
2	Calcium, mEq/L	5.4 (4.7-6.1) S	5.3 (4.7-6.1)	(4.5-6) Bl	5.3 (3.7-6.8)	6.1 (5.6-6.7) S		7.0 (5.6-8.0)
3	Chloride, mEq/L	104 (97-111) S	106 (99-110)		105 (98-115)	102 (98-106)	110 (103-118)	105 (92-112)
4	Copper, µg/100 ml	(130-155) Bl				36 (34-37) Bl		85 (74-99) Bl
5	Iodide, µg/100 ml		29 (14-52) S		7.3 S			
6	Magnesium, mEq/L	2.3 (1.0-2.9) S	1.8 (1.3-2.0)		2.0 S	(1.5-2.1) S		2.0 (1.7-2.5)
7	Phosphate, inorg.	(5.5-6.5) S	5.6 (S)	(3-11) Bl	5.3 S	(3.1-5.6) S		5.9 S
8	Potassium, mEq/L	4.8 (3.9-5.8) S	4.4 (3.7-5.8)		7.4 (6.8-8.9) S	3.3 (2.7-3.5) S	3.3 (2.7-4.7)	4.1 (2.7-5.1) S
9	Sodium, mEq/L	142 (132-152) S	150 (135-160)		145 (140-150) S	149 (146-152) S	145 (143-164)	158 (155-165) S
10	Protein, total, g/100 ml	6.9 (5.7-8.3) S	(6.1-7.8)		5.4 (5.0-5.6) S	7.6 (6.6-8.3) S	6.8 (5.9-7.5)	7.2 (6.0-8.3)
11	Albumin, g/100 ml	3.1 (2.3-3.7) S	(3.1-4.0)		3.2 (2.8-3.9) S	3.1 (2.3-3.8) S		4.6 (4.1-5.1) S
12	Globulin, g/100 ml	3.8 (3.0-5.1) S	(2.0-3.3)		2.2 (1.7-2.6) S	4.5 (3.2-5.3) S		2.7 (1.9-3.6) S
13	α-Globulin, g/100 ml	1.1 S	1.2 S			1.4 S		
14	β-Globulin, g/100 ml	1.9 S	1.3 S			2.1 S		
15	γ-Globulin, g/100 ml	2.3 S	0.8 S			1.4 S		
16	Hemoglobin, g/100 ml	11.1 Bl	13.6 Bl	11.4 Bl		10.1 Bl		
17	Fibrinogen, g/100 ml	0.72	(0.42-0.64)		0.33	(0.29-0.43)	(0.25-0.40)	
18	Glucose	46 (36-57) Bl	60 (44-78) Bl	(43-65) Bl	96 (82-107) Bl	73 (54-95) Bl	148 S	85 (67-107) Bl
19	Lipids, total	350 (185-510)[b]	580 (47-725)		170 (94-245)[b]			245 (69-415)[b]
20	Fat, neutral	105 (0-230)[b]			73 (0-145)[b]			105 (7-205)[b]
21	Phospholipid	84 (17-150)[b]			51 (25-77)[b]			78 (13-145)[b]
22	Cephalin	3 S	22					27
23	Lecithin	54 S	370 (300-470)					86 Ce
24	Sphingomyelin	22 S	55 S					38
25	Cholesterol	110 (8-210)[b]	173 (140-215)	(55-200) Bl	32 (21-43)[b]	77 S	118 S	45 (10-80)[b]
26	Non-protein N	(20-40) Bl	(17-38) Bl	(30-44) Bl	39 (30-51)	(20-40) Bl		
27	Amino acid N							
28	Creatinine	(1-2.1) Bl	(1-1.7) Bl	(0.9-1.8) Bl		(1.2-1.9) Bl		
29	Urea N	(6-27) Bl	(10-20) Bl	(13-28) Bl	19 (8-28) S	(10-20) Bl		15.9 (6.0-25) S
30	Uric acid	(0.05-2.1) Bl	0.33 (0-0.5) Bl	(0.33-1.0) Bl	2.5 (1.3-5.6) S	(0.9-1.1) Bl		2.6 (1.0-4.3) S
31	Adenosine triphosphate	27 Ce	53 Ce			18 Ce		112 Ce
32	Diphosphoglyceric acid		133 Ce			140 Ce		194 Ce
33	Phytic acid	0	0		0	0	0	0
34	Lactic acid	(5-20) Bl	(7-29) Bl			(10-16) Bl		

	Constituent	Rat	Sheep	Swine	Chicken	Reptile[1]	Frog[2]	Fish[3]
35	Water, g/100 ml	86 Bl	87 Bl	83 Bl	87 Bl			
36	Calcium, mEq/L	6.2 (5.4-7.2)[b]	5.7 S	(5.5-5.7) S	5.0 (4.6-5.3)	5.4	3.2	10.8
37	Chloride, mEq/L	110 (105-117) S	116	103 (100-105) S	122 (115-140)	122	70	
38	Copper, µg/100 ml	107[b]		206 (155-260)	14 S			
39	Iodide, µg/100 ml	3.4			7.2			
40	Magnesium, mEq/L	2.9 (2.0-3.7)	1.9 (1.7-2.1)	2.2 (1.9-3.2) S	(1.4-2.0) S	3.4	7.6	1.3 S
41	Phosphate, inorg.	5.9 S	6.9 S	(5.3-9.6) S	(6.2-7.9) S	3.2 S	6.0 S[5]	9.0 S
42	Potassium, mEq/L	5.9 (5.4-6.4)	4.8	5.9 (4.9-7.1) S	6.0 (4.6-6.5)	4.6	4.8	
43	Sodium, mEq/L	151 (143-156) S	160	155 (140-160) S	154 (140-175)	140	105	
44	Protein, total, g/100 ml	6.3	5.7	8.7 (7.9-10.3)	(3.6-6.1) S			
45	Albumin, g/100 ml	(3.4-4.3)[b]	3.1	3.8 (2.1-4.6) S	(1.7-2.5) S			
46	Globulin, g/100 ml	(1.8-2.5)[b]	2.3	4.9 (3.9-5.6) S	(1.8-2.9) S			
47	α-Globulin, g/100 ml		0.96 S					
48	β-Globulin, g/100 ml		1.4 S					
49	γ-Globulin, g/100 ml		2.1 S					
50	Hemoglobin, g/100 ml		10.3 Bl	14 S				
51	Fibrinogen, g/100 ml	(0.16-0.34)[b]	0.36					
52	Glucose	(56-76) Bl	(30-57) Bl	(45-75) Bl	(125-205) Bl	(46-88) Bl	(36-49) Bl[5]	(100-255) Bl
53	Lipids, total	230 (70-415)[b]			520 (340-700)[b]			
54	Fat, neutral	85 (26-145)[b]			225 (63-385)[b]			
55	Phospholipid	83 (36-130)[b]	90 (24-125)[b]	96 (80-130)	155 (84-225)[b]			
56	Cephalin			3 S				
57	Lecithin			72 S				
58	Sphingomyelin			21 S				
59	Cholesterol	52 (28-76)[b]		150 Bl	100 (52-150)[b]			
60	Non-protein N		(20-38) Bl	(20-45) Bl	(20-36) Bl			
61	Amino acid N		(4.6-8) Bl	(8-8.5) Bl	(3.8-9.6) Bl			
62	Creatinine		(1.2-1.9) Bl	(1-2.7) Bl	(0.7-1.2) Bl			
63	Urea N	12.9 (9.6-16.3) S	(8-20) Bl	(8-24) Bl	5.7 Bl			
64	Uric acid	2.5 (1.8-3.0) S	(0.05-1.9) Bl	(0.05-1.9) Bl	4.5 (1.2-7.1) Bl			
65	Adenosine triphosphate	77 Ce	45 Ce	115 Ce	57 Ce	560 Ce[6]	23 Ce[5]	167 Ce[7]
66	Diphosphoglyceric acid	146	<3.5 Ce	190 Ce	0	0		0
67	Phytic acid	0	0	0	250 Ce	95 Ce		
68	Lactic acid	(5-21) Bl	(9-12) Bl					(13-19)[b] Bl

/1/ Turtle (Terrapene carolina) except where indicated. /2/ Rana catesbiana. /3/ Carp, except where indicated. /4/ A value of 320 has been reported. /5/ Species not specified. /6/ Snake. /7/ Catfish.

39. CHANGES IN STORED PRESERVED BLOOD

Values are for whole preserved human blood kept at 4°C and analyzed within 20 minutes after removal from storage. Blood (Bl), red blood cells (RBC); plasma (Pl). All values derived from Rapoport, S., J. Clin. Invest. 26:591, 1947.

	Variable	Preservative[1]	Stored 0 da			Stored 10 da			Stored 20 da			Stored 30 da			Stored 40 da		
			Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl
1	pH^2	C	7.4			7.1			7.1								
2		CD	7.4			7.1			6.8			6.7			6.7		
3		ACD	7.1			6.7			6.6			6.6			6.6		
4	Potassium, mEq/liter	C		100	5		75	23		63	32						
5		CD		100	5		74	20		65	25		60	28		53	34
6		ACD		90	5		75	12		68	19		60	23		53	27
7	Sodium, mEq/liter	C		25	166		45	149		55	142						
8		CD		21	158		40	148		47	145		52	142		58	138
9		ACD		18	160		25	152		30	148		37	142		42	137
10	Inorganic phosphorus, mg/100 ml	C		0	0		35	7		35	10						
11		CD		0	2		10	1		28	6		29	10		31	12
12		ACD		5	2		18	5		25	8		27	9		29	10
13	Lactic acid, mg/100 ml	C	20			80			80								
14		CD	20			135			185			210					
15		ACD	20			90			130			155			170		
16	Glucose, mg/100 ml	C	70			10[3]			5[3]			10					
17		CD	720[4]			650?			575?			520					
18		ACD	670[5]			600?			550?			470					

/1/ Preservative C: 3.2 g trisodium citrate-di-H_2O, in 100 ml aqueous solution, pH 7.5 (effective toxicity re blood = 141%). Ten ml added to 100 ml blood, increasing blood citrate by 10 mM/liter, and plasma citrate by 17 mM/liter. Preservative CD: 2.13 g trisodium citrate-di-H_2O, plus 5 g glucose anhydrous, in 100 ml aqueous solution, pH 7.5 (effective toxicity re blood = 94%). Fifteen ml added to 100 ml blood, increasing blood citrate by 11 mM/liter, and plasma citrate by 19 mM/liter; blood glucose by 650 mg/100 ml. Preservative ACD: 1.33 g trisodium citrate-di-H_2O, plus 470 mg citric acid, plus 3 g glucose anhydrous, in 100 ml aqueous solution, pH 5.03 (effective toxicity re blood = 66%). Twenty five ml added to 100 ml blood, increasing blood citrate by 13 mM/liter, plasma citrate by 21 mM/liter, blood glucose 600 mg/100 ml, citric acid by 16.5 mEq/liter. Blood changes: Blood preserved with C for 8 days shows changes equivalent to those in blood stored for 18 days with CD, and for 33 days with ACD. /2/ pH measured at 37.5°C. Blood and plasma, same pH. /3/ Residual non-fermentable reducing substances. /4/ Normal blood glucose plus glucose in CD. /5/ Normal blood glucose plus glucose in ACD.

40. BLOOD ENZYME ACTIVITY: VERTEBRATES

Values in parentheses are ranges, and, when accompanied by a literal superscript, are estimates of the 95% range (cf Introduction). B = blood, C = RBC; P = plasma; S = serum.

	Animal	Activity/100 ml		
	Adenosine Deaminase[1]			
1	Rabbit	B	415	
	Adenosine Polyphosphatase, Acid[2]			
2	Man	S	141(81-180)	
	Adenosine Polyphosphatase, Alkaline[2]			
3	Man	S	30(10-51)[b]	
	Adenylic Acid Deaminase, Muscle[3]			
4	Rabbit	B	41	
	Aldolase[4]			
5	Man	S	(350-800)[4]	
6		C	?	
7	Rat, albino	C	90,000	
8		S	6000	
	Amylase[5]			
9	Man	S	(80-150)[b]	
	Arginase[6]			
10	Man	C	25100	
11		C	? 4400	
12		B	?2000	
13	Monkey	P	0	
14	Mouse	P	0	
	Carbonic Anhydrase[7]			
15	Man	C	73,000	
16	Cat	C	128,000	
17	Calf	C	44,000	
18	Dog	C	84,000	
19	Guinea pig	C	50,000	
20	Swine	C	59,000	
21	Rat	C	144,000	
22	Chicken	C	22,000	
	Catalase			
23	Man	C	0.19	

	Animal	Activity/100 ml		
	Catalase (concluded)			
24	Man	S	6?69	
25	Cow	B	202, 800[10]	
	Cholinesterase			
26	Man	B	336[11]	
		C	542[11]	
		P	176[11]	
27	Man	S	(135-362)[12]	
28	Dog	S	(92-140)[12]	
29		S	(112-303)[12]	
30	Guinea pig	S	(125-230)[12]	
31	Horse	S	(248-310)[12]	
32	Mouse	S	(430-685)[12]	
33	Ox	S	45[12]	
34	Swine	S	46[12]	
35	Rabbit	S	(18-35)[12]	
41	Rat	C	253[13]	
42	Sheep	S	0[12]	
43	Chicken	S	(28-78)[12]	
	Cholinesterase[14, 15, 16]			
44	Man	C	261	
45		P	5.8	
46	Cat	C	12.1	
47		P	16.2	
48	Cow	C	211	
49		P	Trace	
50	Dog	C	61	
51		P	14.8	
52	Guinea pig	C	193	
53		P	16.6	
54	Horse	C	81	
55		P	8.1	
56	Rabbit	C	34	
57		P	25.2	
58	Rat	C	?	
59		P	16.2	

	Animal	Activity/100 ml	
	Cholinesterase[14, 15, 16] (concluded)		
60	Sheep	C	76
61		P	13.0
62	Fowl	C	Trace
63		P	?2
64	Labrus (bony fish)	C	0
65		C	0.3
66	Scyllium (elasmobranch)	C	0
67		P	?.6
68	Man	C	Trace
69		P	?10
70	Cat	C	0
71		P	45
72	Cow	C	Trace
73		C	Trace
74	Dog	C	0
75		P	?44
76	Guinea pig	C	Trace ·
77		P	60
78	Horse	C	Trace
79		P	243
80	Rabbit	C	0
81		P	19.8
82	Rat	C	0
83		P	5.8
84	Sheep	C	0
85		P	0
86	Fowl	C	Trace
87		P	4.5
88	Labrus (bony fish)	C	Trace
89		P	Trace
90	Scyllium (elasmobranch)	C	0
91		P	Trace

	Animal	Activity/100 ml	
	Dehydroperidase[18]		
92	Man	S	359
	Glucose-6-phosphate Dehydrogenase		
93	Rat	C	+
	β-Glucuronidase[19]		
94	Man	S	(70-181)
95		S	2 (37-230)
	Glycolase[20]		
96	Man	C	1, 368, 000
97		B	611, 700
98	Rat	C	2, 040, 000
99		B	861, 000
	Hexokinase		
100	Rat	C	+
	Histaminase[21]		
101	Man	B	36(30-40)
102		S	18(0-36)
	Lactic Dehydrogenase		
103	Man	S	+
104		C	+
	Lipase[22]		
105	Man	S	(0-150)
	Methemoglobin Reductase		
106	Man	C	+
	Phenosulfatase[23]		
107	Man	S	(30-150)
	Phosphatase, Acid[24]		
108	Man	S	(1.0-4.0)
	Phosphatase, Alkaline[25]		
109	Man, adult	S	(10.5-13.0)[26]
110			(1.0-4.0)[27]
111	Child	S	(5.0-14.0)[28]
	Profibrinolysin[29]		
112	Man	P	(50-125)
	Vitamin K_1 Conjugase[30]		
113	Man	P	(80-100)

/1/ μg N liberated/hr. /2/ μM P from ATP/hr at pH 4.8 for acid adenosine polyphosphatase, and at pH 8.9 for alkaline adenosine polyphosphatase. Corrected for inorganic P and non-enzymatic hydrolysis. /3/ μg N liberated/hr in presence of 0.09% adenylic acid. /4/ μl fructose diphosphate/hr at 38°C at pH 8.6. No change in pregnancy. /5/ mg dextrose or equivalent (by copper reduction) from starch under specified conditions. /6/ Units as described by Kochakian. Fall in malnutrition. /7/ Amount of RBC that will halve the time of uncatalyzed reaction at 3°C under specified conditions. Fall in newborn; parallels RBC Zn concentration in all conditions in addition. /8/ g/100g dry weight. /9/ Units described by Dülle, et al. /10/ mg H_2O_2 split/10 min under conditions specified. /11/ μM acetylcholine hydrolyzed/min as measured by ml 0.01 N NaOH required to neutralize acetic acid formed/min from 0.0025M acetylcholine at pH 7.65 at 25°C. /12/ μM acetylcholine hydrolized/min from 0.01M acetylcholine. /13/ μM acetylcholine hydrolyzed/min from 0.015M acetylcholine. /14/ μM acetyl-β-methylcholine hydrolyzed/min as measured by volume CO_2 evolved/min from 0.03M acetyl-β-methylcholine. /15/ Hemstocrit values of 45 assumed. /16/ RBC cholinesterase activity high in reticulocytes and young cells; high in conditions accompanied by hyperactive hematopoiesis. /17/ μM benzoylcholine hydrolyzed/min as measured by volume CO_2 evolved/min from 0.006M benzoylcholine. /18/ μMNH3/30 min from α-alanyldehydroalanine at 37°C at pH 8.1. /19/ μg phenolphthalein/hr from phenolphthalein-glucuronide at 38°C at pH 4.5. Rise in pregnancy from 300 μg at 3 months to 1350 μg at term. /20/ μl CO_2/20 min from methylglyoxal at pH 7.2 at 26°C in presence of glutathione. /21/ μg histamine destroyed in 90 min at 37°C. Rise in pregnancy. /22/ ml N/20 NaOH/24 hr from standard olive oil emulsion. /23/ Amount of enzyme which produces color equivalent to 10 μg of p-nitrophenol from p-nitrophenyl sulfate. /24/ mg phenol/hr from disodium phenylphosphate at 37°C at pH 5.0. /25/ Rise in osteoblastic activity and pregnancy. /26/ mg phenol/30 min from disodiumphenylphosphate at 37.5°C at pH 9.0. /27/ mg P/hr from β-glycerophosphate at 37°C at pH 8.6. /28/ mg P/hr from β-glycerophosphate at 37°C at pH 8.6. /29/ Units of fibrinolysin. A unit will completely lyse a 0.1% fibrin clot in 120 seconds at 28°C at pH 7.2 in isotonic saline buffered with imidazole. /30/ μg folic acid/90 min from yeast extract at 37°C at pH 4.5.

41. SEROUS FLUIDS, CHEMICAL CHARACTERISTICS: VERTEBRATES

The concentrations in transudates of constituents of blood will depend on the plasma concentration of the constituent, the membrane permeability of the constituent and, in the case of electrolytes, the charge of the ion and the concentrations of non-diffusible ions (proteins) in the plasma and in the transudate. For non-electrolytes readily passing through the membrane, the concentration in transudate water will equal that in plasma water provided a steady state is present. In the case of electrolytes, the concentrations in the transudate will differ from that in plasma according to the Gibbs-Donnan law for heterogeneous solutions. Values are mg/100 ml, unless otherwise indicated. Those in parentheses are ranges, and unless followed by a superscript, are estimate "of" range (of Introduction).

	Constituent or Property	Animal	Plasma	Transudates	Pleural Fluid	Pericardial Fluid	Peritoneal Fluid
1	Water, %	Man	94 (93-95)	94 (90-99)	98 (96.4-99)		(95-99)
2		Dog	93 (91-95)	98. 9 (98. 3-99. 3)			
3		Horse	91	(93. 5-95. 8)			
4	Ash, %	Man	(0. 6-1. 0)		0.76	0.67	0.98
5	pH	Man	7.39 (7.33-7.45)[b]	(7.45-7.68)	7.2 (6.8-7.6)		7.4 (6.8-9.8)
6		Turtle	7.72 (7.46-7.80)			8.25 (7.9-8.5)	8.12 (7.8-8.4)
7		Fish	7.36 (7.2-7.6)	7.45 (7.1-7.6)		6.12 (5.3-6.9)	5.80 (5.4-6.3)
8	Conductivity, mhos x 1000	Man	(10. 5-12. 4)	14.2 (11.3-15.5)			13.4 (13.2-13.5)
9	Calcium, mEq/L	Man	4.8 (4.3-5.2)	4.0 (2.6-4.9)			
10		Dog	5.3 (4.7-6.1)	3.5 (3.2-4.1)	4.3 (2.8-5.4)		4.0 (2.0-4.9)
11		Turtle	5.4 (3.1-6.5)	2.4		2.1 (0.6-4.5)	3.4 (2.4-5.2)
12		Fish	4.9 (2.9-6.0)	4.6 (3.0-6.9)		1.8 (0.5-3.5)	3.4 (1.7-6.6)
13	Carbon dioxide, mEq/L	Man	29.5 (23-33)	28.7 (22-37)	23.8 (21-31)		26.7 (24-29)
14		Dog	24 (17-27)	26.1 (21-31)			21.4 (10-30)
15		Turtle	40.4 (23-52)	44		88.5 (29-130)	68.9 (24-130)
16		Fish	8.2 (6-12)	7.3 (5-10)		0.4 (trace-0.5)	0.3 (trace-0.4)
17	Chloride, mEq/L	Man	102 (93-110)	105.8 (98-110)	100 (92-135)	124.8	109 (91-120)
18		Dog	106 (99-110)	126 (119-127)			124 (110-145)
19		Turtle	112	75.6		55.1 (15-130)	70.8 (33-125)
20		Fish	236 (225-265)	262 (245-280)		370 (365-375)	274 (190-330)
21	Magnesium, mEq/L	Man	1.8 (1.7-1.9)	2.0 (1.6-2.4)	1.7 (0.7-2.4)		0.5
22		Dog	1.8 (1.3-2.0)	1.7 (1.4-2.2)			
23		Turtle	3.4 (0.5-7.9)	0.8		1.1 (0.3-3.5)	2.1 (0.3-5.0)
24		Fish	2.8 (1.7-3.5)	1.0 (0.9-1.0)		2.6 (1.0-5.0)	17.8 (8.0-25.0)
25	Phosphorus, total	Man	23 (19-29)		11.4 (6-31)		
26		Dog	26	(12-18)			
27	Phosphorus, inorg.	Man	3.4 (2.4-4.4)	3.0 (1.2-4.4)	3.8 (2.1-5.1)		4.0 (1.2-5.3)
28		Fish	19.8 (9-40)	12	5.6 (0-11)	4.3 (0-8.7)	5.6 (0-11)
29	Potassium, mEq/L	Man	5.6	3.4 (2.8-6.0)	4.8 (2.5-6.6)		4.1 (2.0-5.6)
30		Dog	4.4 (3.7-5.8)	5.0 (4.2-6.1)			
31		Turtle	4.6 (2.4-6.7)	2.0		3.1 (1.1-6.1)	3.2 (2.4-4.3)
32		Fish	5.3 (4.5-6.8)	4.8 (3.8-6.0)		16.6 (8.5-22)	6.6 (5.2-8.9)
33	Sodium, mEq/L	Man	(140-155)	140 (120-155)	140 (135-150)		138 (125-155)
34		Dog	150 (135-160)	150 (145-155)			
35		Turtle	138 (120-165)	123		140 (130-150)	137 (120-150)
36		Fish	259 (235-275)	266 (260-270)		314	246 (145-305)
37	Nitrogen, total	Man	(3000-3700)	(320-835)	287 (260-340)		150 (65-555)
38		Dog					149 (26-295)
39	Protein, g/100 ml	Man	(6.5-7.4)	0.85 (0.4-1.3)	1.8 (0.3-4.1)	3.3 (0.8-4.9)	2.1 (0.02-4.5)
40		Cat	7.6 (6.1-9.0)			2.4 (2.2-2.7)	(0.6-2.5)
41		Dog	6.7 (6.1-7.8)	3.0 (0.2-4.8)		1.7 (0.8-2.9)	2.6 (1.6-3.7)
42		Monkey	6.8 (5.9-7.5)			1.7 (1.3-2.2)	
43		Rabbit	5.7			2.2 (1.5-3.6)	
44		Rat	6.3			2.1	
45		Chicken	3.6 (2.6-4.6)			3.5	
46	Albumin, g/100 ml	Man	4.4 (4.0-4.8)	2.2	0.97 (0.8-1.2)	2.2	0.88 (0.3-1.6)
47		Dog	(3.1-4.0)			1.0 (0.7-1.5)	
48	Globulin, g/100 ml	Man	2.5 (1.8-3.3)	0.6	0.79 (0.3-1.2)	0.6	0.81 (0.2-1.7)
49		Dog	(2.0-3.3)			0.75 (0.4-1.5)	
50	Albumin-globulin ratio	Man	1.7 (1.3-2.2)	(2.5-3.5)	1.5 (0.9-3.5)		1.1 (0.9-1.6)
51		Dog	1.4				1.6 (0.7-2.6)
52	Euglobulin, g/100 ml	Man	0.2		(0.7-1.1)		
53	Pseudoglobulin, g/100 ml	Man	1.8		(1.8-2.2)		
54	Fibrinogen	Man	0.29	0.03 (0-0.8)	0.1 (0-0.3)	0.03	0.1 (0-0.2)
55		Horse	(0.29-0.43)	(0.04-2.2)			
56	Non-protein nitrogen	Man		(27.5-30)	31 (20-42)		30.2 (20-43)
57		Dog		34 (20-45)			
58		Fish	1090 (1070-1125)	680			870 (760-1015)
59	Amino acid N	Man		6.4	5.6 (4.2-8.9)		
60		Fish	7.5 (5.6-9.4)				(0-2.6)
61	Ammonia	Man	0.18 (0.12-0.24)	1.2			
62	Creatine	Man	0.23 (0-0.8)	3.2	3.0 (2.1-4.9)		
63		Fish	2.9 (1.8-4.2)	2.4			3.9 (3.6-4.2)
64	Creatinine	Man	0.91 (0.87-0.95)	2.4	1.2 (0.7-2.1)		1.2 (1.0-2.0)
65		Fish	(0-0.5)			0	(0-0.7)
66	Purine N	Man		0.39			
67	Urea N	Man	14 (5-22)	14.4	13 (9.8-22)		16 (11.9-21)
68		Dog		11 (9.9-16.5)			
69		Fish	1180 (1045-1300)	970 (655-1240)		1065 (690-1345)	1015 (900-1100)
70	Uric acid	Man	3.2 (2.2-4.2)	4.0 (2.5-5.0)	4.0 (1.9-8.0)		4.2 (1.8-5.3)
71		Dog	0.33	Trace			
72	Lipid, total, g/100 ml	Man	(0.38-6.67)	1.5 (0.7-2.5)			
73	Fatty acids	Man	315 (295-340)		268 (130-430)		
74	Cholesterol	Man	(195-230)	40 (13-60)	147 (20-329)		60 (5-150)
75	17-OH-corticosteroids, µg/100 ml	Man	13 (2-34)	3 (0-11)	8 (0-16)	(5-16)	4.2 (0-9)
76	Phosphatides	Man	165 (110-220)	142			164
77	Lecithin	Man	117	(60-150)	50 (0-125)		40 (0-140)
78	Lactic acid	Man	36	(17-32)	17.8 (11-47)		
79	Bilirubin	Man	0.18 (0.1-0.25)	(0-0.2)	(0.1-0.7)		0.5

42. LYMPH, CHEMICAL COMPOSITION: MAMMALS

Values in this table are the result of a four-year search for data in the field of lymph composition. Numerous gaps point up lack of available information and/or need for research. Values are mg/100 ml, unless otherwise indicated.

	Constituent	Species	Thoracic Duct		Skin Lymphatics		Cervical Lymphatics		Right Lymph Duct		Intestinal Lymphatics		Liver Lymphatics		Leg Lymphatics	
			Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph
1	Calcium	Man	9.5	7.7												
2		Dog	10.4	9.2			11.7	9.8								
3	Chloride	Man	335	335												
4		Dog	390	415			410	430								
5	Phosphorus, inorganic	Man	4.0	3.9												
6		Dog	4.3	3.6			5.6	5.9								
7	Potassium	Man	19.1	18.3												
8		Dog		18.7			16.4			21.1						
9	Sodium	Man	290	290												
10		Dog		330			375	360								
11	Protein, g/100 ml	Man	6.0	2.8-3.6	0.7											
12		Cat	7.6	4.8				3.5	7.4	4.9	5.8		5.3	5.2		3.3
13		Dog	6.2	4.0			6.2	3.6			5.7	2.8	5.7	4.4	5.5	1.7
14		Rat	5.8	3.1				3.1								
15	Albumin, g/100 ml	Man	3.5	1.6-2.4												
16		Dog	3.6	2.4			3.6	2.4			3.5	1.9	3.4	2.7		
17		Rat	3.9	1.9												
18	Globulin, g/100 ml	Man	2.5	1.2												
19		Dog	2.6	1.5			2.6	1.3			1.6	0.6	1.8	1.3		
20		Rat	1.9	1.2												
21	Fibrinogen, g/100 ml	Man														
22		Dog	0.4	0.2												
23	Prothrombin, %[1]	Man														
24		Dog		51										93		7.6
25	Amino acids	Man														
26		Dog	2.4	2.4			4.9	4.8								
27	Non-protein N	Man	25.7	23.4												
28		Dog	40.0	39.0			37.5	37.4	30.0	31.0					27.2	26.7
29	Urea	Man														
30		Dog		23.5			21.7	23.5								
31	Creatinine	Man	1.1	1.0												
32		Dog					1.4	1.4								
33	Glucose	Man	135	136												
34		Dog	125	125			125	130			220	220			110	115
35	Non-fermentable	Man														
36	reducing substances	Dog					5.5	5.8								
37	Total lipid, g/100 ml	Man														
38		Dog	0.3-0.6	0.2-7.3			0.6	0.3								
39	Fatty acids	Man														
40		Dog					440	240								
41	Cholesterol	Man	120	75												
42		Dog					135	55			72	48				
43	CO_2 Content	Man														
44		Dog					57[2]	59[2]								
45	pH	Man														
46		Dog					7.3	7.4								

/1/ Percentage of level in plasma. /2/ ml/100 ml.

43. SWEAT, CHEMICAL COMPOSITION: MAN

Values are mg/100 ml of sweat, unless otherwise indicated. Those in parentheses are averages of ranges reported in the literature.

	Constituent	Value		Constituent	Value
1	Water, %	(99.2-99.7)	25	Threonine	5.4(1.7-9.1)
2	Calcium	2.1(1-8)	26	Tryptophan	1.1(0.4-1.8)
3	Chloride	(30-300)	27	Tyrosine	3.2(1.2-5.0)
4	Iodine, µg	0.8(0.5-1.2)	28	Valine	3(1.5-4.5)
5	Iron, µg	279(22-45)	29	Reducing substances,as glucose	(2.8-40)
6	Magnesium	0.2(0.14-4.5)	30	Volatile acids, ml 0.1 N	(2.4-5.6)
7	Manganese, µg	6(3-7)	31	Lactic acid	225(45-452)
8	Nitrogen, ammonia	(2.5-35)	32	Ascorbic acid[1], µg	(0-200)
9	Nitrogen, total	31(27-64)	33	Biotin, µg	Trace
10	Phosphorus	0.5 (0-2)	34	Choline, µg	(0.3-1.5)
11	Potassium	(21-126)	35	Folic acid group, µg	0.6(0.53-0.88)
12	Sodium	(29-294)	36	Inositol, µg	21(15-36)
13	Sulfur, total	(0.7-7.4)	37	Nicotinic acid, µg	(7-22)
14	Non-protein nitrogen	31(27-64)	38	Pantothenic acid, µg	3.8(2.2-4.4)
15	Amino acid N	2.8(1.6-4.8)	39	p-Aminobenzoic acid, µg	0.24(0.08-1.7)
16	Creatinine	(0.1-1.3)	40	Pyridoxine, µg	(0.08-0.18)
17	Urea	(12-57)	41	Pyridoxal, µg	3.2(0.4-8.25)
18	Uric acid	1.4(0.7-2.5)	42	Riboflavin, µg	(0-0.5)
19	Arginine	13.5(5.8-21.4)	43	Thiamine, µg	0.15(0-0.6)
20	Histidine	8.0(6-10)	44	Specific gravity	(1.001-1.006)
21	Isoleucine	2.3(1.0-3.6)	45	pH	(3.8-6.5)
22	Leucine	2.7(1.2-4.2)	46	Maximum rate of production, ml/min	(17.7-38.2)
23	Lysine	2.3(1.4-3.2)	47	Stimulus to sweating[2], °C	(39-45)
24	Phenylalanine	2.2(1.0-3.5)			

/1/ Includes dehydroascorbic acid. /2/ Thermally induced, average skin temperature at rest.

44. CEREBROSPINAL FLUID: PHYSICAL AND CHEMICAL CHARACTERISTICS

Values are mg/100 ml unless otherwise indicated; those in parentheses are ranges.

Part I: MAN

	Constituent or Property	Value		Constituent or Property	Value		Constituent or Property	Value
1	Volume, ml	(90-150)	22	Protein, total	28(12-43)	43	Isoleucine N	0, 01
2	Specific gravity	1, 0071(1, 0062-1, 0082)	23	Cisternal	15	44	Leucine N	0. 01
3	Solids, total	1000(850-1700)	24	Lumbar	25(20-40)	45	Lysine N	0, 05
4	Freezing point, °C	-0, 570(-0, 60 to -0, 054)	25	Ventricular	10	46	Methionine N	0, 004
5	pH	7, 4(7, 35-7, 70)	26	Albumin, %[1]	55(40-70)	47	Phenylalanine N	0, 02
6	Pressure, mm H_2O	150(70-180)	27	Fibrinogen	0	48	Threonine N	0, 03
7	Aluminum	Trace	28	α-Globulin[1]	10(5-20)	49	Tyrosine N	0, 01
8	Barium	Trace	29	β-Globulin[1]	12(5-20)	50	Valine N	0, 02
9	Bicarbonate	48	30	γ-Globulin[1]	11(5-20)	51	Cholesterol	0(0, 24-0, 50)
10	Boron	Trace	31	X-protein[1, 2]	7(2-15)	52	Fatty acids	(1-3)
11	Calcium	5(4, 5-5, 2)	32	Non-protein N	19(12-28)	53	Reducing substances[3]	70(44-110)
12	Chloride	440(420-450)	33	Creatinine	1, 2(0, 5-1, 9)	54	Fructose	3, 4(2, 0-7, 5)
13	Copper	0, 013(0, 006-0, 02)	34	Urea	11, 7(8-28)	55	Hexosamine	9(5-18)
14	Iodine	<0, 005	35	Uric acid	(0, 07-2, 8)	56	Polysaccharides	3, 4(2, 3-6, 8)
15	Magnesium	2, 36(2, 0-2, 6)	36	Amino acid N	1, 23	57	Ascorbic acid	0, 6(1-8)
16	Phosphorus	1, 5(1, 2-2, 1)	37	Alanine N	0, 21	58	Citric acid	0, 04
17	Potassium	9, 8(8, 5-13, 2)	38	Arginine N	0, 1	59	Lactic acid	17(11-27)
18	Sodium	525(500-545)	39	Cystine N	0, 02	60	Pyruvic acid	(0, 4-1, 0)
19	Strontium	Trace	40	Glutamine N	0, 73	61	Acetylcholine	0
20	Sulfur	0, 6	41	Glycine N	0, 03	62	Cholinesterase[4]	Present
21	CO_2, vol %	59(57-62)	42	Histidine N	0, 05	63	Glucuronidase[5]	Present

/1/ Per cent of total protein. /2/ 2 components migrating in electrophoresis more rapidly than albumin at pH about 8; not lipoproteins. /3/ Includes glucose. /4/ About 1% of serum concentration. /5/ An unidentified esterase is also present.

Part II: VERTEBRATES

	Constituent or Property	Value		Constituent or Property	Value		Constituent or Property	Value
	Cat			Dog (concluded)			Monkey (concluded)	
1	Calcium	6	27	Uric acid	0, 24		Protein, total (concluded)	
2	Chloride	425	28	Allantoin	0, 3(0, 25-0, 47)	52	Cisternal fluid	(8-15)
3	Protein, lumbar fluid	17	29	Glucose	63	53	Lumbar fluid	(20-30)
4	Glucose	58	30	Ascorbic acid	6, 6	54	Globulin	(0, 4-6, 3)
5	Ascorbic acid	3, 8		Goat		55	Glucose	54
	Cattle		31	Specific gravity	1, 0049	56	Ascorbic acid	2, 3
6	Specific gravity	1, 0065(1, 005-1, 008)	32	Chloride	410		Rabbit	
7	pH	7, 5(7, 4-7, 6)	33	Protein, lumbar fluid	12	57	Specific gravity	1, 005
8	Pressure, mm H_2O	(80-150)	34	Glucose	56	58	Chloride	(600-730)
9	Calcium	8(5, 2-6, 1)		Horse		59	Protein, total	(15-19)
10	Chloride	410	35	Specific gravity	1, 0065(1, 004-1, 008)	60	Non-protein N	(5, 6-16, 8)
11	Potassium	(11, 2-13, 8)	36	pH	7, 25(7, 13-7, 36)	61	Glucose	(50-57)
12	Protein, total	(22-27)	37	Pressure, mm H_2O	380(270-490)		Shark	
	Lumbar fluid	34	38	Calcium	6, 3(5, 5-7)	62	Specific gravity	(1, 0233)
14	Albumin	(10-22)	39	Chloride	450	63	pH	7, 2
15	Non-protein N	16	40	Magnesium	2, 0(1, 1-2, 9)	64	Uric acid	0, 14
16	Creatinine	1, 4	41	Phosphorus, inorganic	1, 4(0, 9-2, 2)		Sheep	
17	Urea	11	42	Potassium	12, 7(10, 6-14, 2)	65	Calcium	5, 8
18	Glucose	(48-68)	43	Protein, total	47, 6(29-72)	66	Chloride	(750-870)
	Dog		44	Cisternal fluid	50(30-66)	67	Magnesium	2, 9
19	Specific gravity	1, 0065(1, 006-1, 009)	45	Albumin	38, 6(22, 6-68)	68	Protein, total	(8-70)
20	pH	7, 37(7, 35-7, 39)	46	Globulin	9, 3(3, 4-18, 4)	69	Non-protein N	29(9, 6-42)
21	Pressure, mm H_2O	145(30-230)	47	Urea	(23-31)	70	Glucose	(48-110)
22	Chloride	410	48	Glucose	56(49-76)		Swine	
23	Protein, cisternal fluid	30	49	Ascorbic acid	1, 7	71	Protein, total	(24-29)
24	Protein, lumbar fluid	12		Monkey		72	Albumin	(17-24)
25	Albumin	(10-25)	50	Chloride	420	73	Globulin	(5-10)
26	Globulin	9	51	Protein, total	(8-50)	74	Glucose	(45-85)

45. SEBUM, CHEMICAL COMPOSITION

Sebum denotes the lipid obtained by extracting the intact skin or hair or wool; in birds, the lipid is from the green gland oil. Values are g/100 g; those in parentheses are ranges.

	Constituent	Man[1]	Guinea Pig	Ox	Rabbit	Rat	Sheep	Duck	Goose
1	Fatty acids, free, total	28, 3(22, 0-32, 2)	8, 2	5, 1	9, 0	7, 4	11, 0		
2	Straight-chain	28, 3							
3	Branched-chain	0							
4	Fatty acids, combined[2], total	34, 6(27, 5-41, 0)	50, 5	53, 4	43, 6	51, 4	44, 0	47, 6	47, 5
5	Straight-chain	34, 6					3, 5	14, 8	9, 5
6	Branched-chain	0					25, 0	32, 8	38, 0
7	Hydroxy	0					15, 0		
8	Triglycerides	32, 5	0		0	0	0		
9	Unsaponifiable matter, total	30, 1(25, 1-35, 9)	36, 7	42, 7	45, 9	41, 4	(40-50)		
10	Squalene	5, 5(3, 3-11, 2)	0		0	0	0(?)		
11	Hydrocarbons	9, 1(5, 0-20, 0)	1, 5		3, 4	1, 5	cl		
12	Aliphatic alcohols, total	6, 2(4, 7-6, 9)	2, 6		30, 3	16, 9	9, 0	48, 0	48, 0
13	Straight-chain	2, 4					1, 5	48, 0	48, 0
14	Branched-chain	3, 8					7, 5	0	0
15	Cholesterol	4, 1(2, 7-6, 9)	15, 0[3]	14, 4	3, 9	10, 1[3]	10, 0(4, 6-12, 5)	1, 4	0, 25
16	Dihydrocholesterol	0, 1					2, 5		
17	Isocholesterol[4]	0			0		12, 5		
18	Aliphatic diols						2, 5		

/1/ Adult forearm. /2/ As triglycerides, waxes and other esters. /3/ Cholesterol plus Δ^7-isomer. /4/ A mixture of lanosterol, dihydrolanosterol, agnosterol, and dihydroagnosterol. Also present in sebum of goat (2.5%), camel (2.2%) and llama (1.2%).

46. SYNOVIAL FLUID, PHYSICAL AND CHEMICAL CHARACTERISTICS: MAMMALS

Values in parentheses are estimate "d" of the 95% range (cf. Introduction).

	Constituent or Property	Man, Knee Joint	Cattle Astragalotibial Joint	Horse Astragalotibial Joint
1	Volume, ml	1. 1(0. 13-3. 5)	25(5-65)	(5-40)
2	Solids, total, %	3. 4(1. 2-4. 8)	2. 1(1. 7-3. 9)	
3	pH	7. 39(7. 29-7. 49)	7. 31(7. 27-7. 43)	
4	Viscosity, relative	235(5. 7-1160)[1]	9(2-12)[2]	(3-29)[3, 4]
5	Specific gravity	(1. 008-1. 015)	(1. 009-1. 012)	
6	Freezing point, °C		(-0. 51 to -0. 55)	
7	Osmotic pressure, mm H_2O		150(125-170)	
8	Bicarbonate, mEq/L		28. 5(25-32)	
9	Calcium, Ft/Se[5]	0. 87	0. 83	0. 97
10	Chloride, Se/Fl ratio[6]	0. 98	0. 99	0. 98
11	Magnesium, mEq/L		1. 4(1. 3-1. 7)	
12	Phosphorus, mEq/L		2. 2(1. 5-3. 0)	2. 6(1. 8-3. 6)[7]
13	Potassium, mEq/L	4.0	4. 0(3. 6-4. 4)	
14	Sodium, mEq/L	135	145(140-148)	
15	Sulfate, mEq/L		5. 0(4. 5-5. 4)	
16	CO_2, mm Hg		58. 8(50-70)	
17	Base, total, mEq/L		165(150-180)	
18	Protein, total, g/100 ml	2. 8	0. 9(0. 4-1. 4)	1. 4(0. 9-1. 9)[4]
19	Albumin, g/100 ml	1. 9	0. 7(0. 5-0. 9)	1. 2
20	Globulin, g/100 ml	0. 9	0. 2	
21	β-Globulin, g/100 ml			0. 32
22	α-Globulin, g/100 ml			0. 37
23	Fibrinogen	0	0	
24	Mucin, g/100 ml	0. 85	0. 14(0. 03-0. 25)	0. 47(0. 3-0. 7)[4]
25	Mucin, N, g/100 ml	0. 1(0. 07-0. 13)	(0. 06-0. 2)	0. 04(0. 03-0. 05)
26	Mucin glucosamine, g/100 ml	0. 07(0. 05-0. 13)	(0. 02-0. 05)[8]	
27	Non-protein N, Se/Fl ratio[6]	0. 91	0. 87	1. 05
28	Uric acid, mg/100 g	1. 9	1. 5(1. 2-2. 1)	5. 3(5-5. 6)
29	Sugar, reducing, mg/100 g	Same as plasma	65(45-95)	(77-82)
30	Hyaluronic acid, mg/100 g	155(4-295)	(20-25)	56

/1/ Hess and Ostwald viscosimeter, 25°C. /2/ Scott-Blair viscosimeter, 20°C. /3/ Hess viscosimeter, 20°C. /4/ Carpal joint. /5/ Square root of distribution ratio: synovial fluid/serum concentration. /6/ Distribution ratio, serum concentration/synovial fluid concentration. /7/ mg/100 g. /8/ Joint not specified.

47. BODY FLUIDS, ELECTROLYTE AND NITROGEN BALANCE IN NORMAL PREGNANCY: MAN

Part I: BLOOD AND URINE

Values are mg/100 ml, unless otherwise indicated; those in parentheses are estimate "b" of the 95% range (cf. Introduction).

	Constituent or Property	Fluid	Value
1	pH	Blood	7. 4
2	Calcium	Serum	9. 58
3	Chloride	Serum	580
4	Iodine, μg/100 ml	Plasma	11
5	Phosphorus	Serum	3. 21
6	Potassium	Serum	16. 0
7	Sodium	Serum	330
8	CO_2, vol %	Serum	48
9	Base, total, mM	Serum	147
10	Protein, total, %	Serum	6. 35
11	Albumin, %	Serum	3. 88
12	Globulin, %	Serum	2. 47
13	Fibrinogen, %	Plasma	0. 35
14	Nitrogen, total[1], g	Urine	8-12
15	Non-protein N	Blood	28. 0
16	Urea N	Blood	12. 5
17	Urea N, % of total N	Urine	70-85
18	Uric acid	Blood	3. 0
19	Creatinine	Blood	1-2
20	Ammonia N[2]	Urine	3-5
21	Glucose	Blood	80
22	Lipids, %	Blood	0. 9
23	Fat, neutral	Plasma	359(200-500)
24	Phospholipid	Plasma	250(160-335)
25	Cholesterol, ester	Plasma	140(45-235)
26	Cholesterol, free	Plasma	65(35-95)
27	Phosphatase, B.U.[3], %	Serum	6, 6

/1/ Per 24 hours. /2/ % of total nitrogen. /3/ Bodansky units.

Part II: AMNIOTIC FLUID

Values are mg/100 ml, unless otherwise indicated.

	Constituent or Property	Value
1	Volume, ml	700[1]
2	Water, %	98. 5
3	Specific gravity	1. 006-1. 008
4	Calcium	5. 5
5	Phosphorus	3. 1
6	Sodium	280
7	Protein, total, %	0. 53
8	Non-protein N	24-25
9	Uric acid	4. 5
10	Sugar, reducing	19

/1/ At term.

Part III: FLUID BALANCE

Values are liters, unless otherwise indicated.

	Constituent or Property	Value[1]	% of Body Weight
1	Body water*, total	40	55
2	Extracellular space[3]	16	22
3	Sodium space[4]	20	28
4	Amniotic fluid volume	0. 7	
5	Blood volume	5. 4	
6	Water content of blood, %	83	
7	Plasma volume[5]	3. 3	4. 8
8	Cell volume	1. 9	
9	Hematocrit, %	38	

/1/ Average values at term. /2/ Antipyrine volume. /3/ Inulin volume. /4/ Na^{24} volume. /5/ Gregersen method.

Part IV: ELECTROLYTE AND NITROGEN BALANCE

Values are mg in 24 hr urine sample.

	Constituent or Property	Value
1	Calcium	+280
2	Chloride	+0. 88
3	Iron	+1-1. 5
4	Nitrogen	+1360
5	Phosphorus	+210
6	Potassium	+0. 51
7	Sodium	+1, 26

Values are mg/100 ml, unless otherwise indicated; those in parentheses are ranges and, unless accompanied by superscript, are estimate "of" of the 95% range (cf Introduction). Data for additional species are given in the footnotes. (SP) indicates that values are for seminal plasma.

	Constituent or Property	Prostatic Fluid		Semen						
		Man[1]	Dog[2]	Man	Cattle	Dog	Horse	Rabbit	Sheep	Swine
1	Volume of ejaculate[3], ml	13-32% of semen	97% of semen	3.5(2.0-6.0)	4.0(2.0-10.0)	6.0(2.0-15.0)	70(30-300)	1.0(0.4-6.0)	1.0(0.7-2.0)	250(150-500)
2	Spermatozoa[4], millions/ml	0	0	100(50-150)	1000(300-2000)	3000(1000-9000)	120(30-800)	700(100-2000)	3000(2000-5000)	100(25-300)
3	Spermatozoa, size[4], μ			55;5x4x1;5;45	65;9x4x1;13;44	60;7x4x1;10;44	58;7x4x2;10;42	56;9x1x1;9;39		57;8x4x1;11;38
4	Specific gravity	1.022(1.018-1.027)	(1.006-1.008)	1.035(1.031-1.039)	1.034(1.015-1.053)	1.011				
5	Freezing point depression, °C			0.54(0.51-0.58)	0.61(0.54-0.73)	(0.58-0.60)	0.60(0.58-0.62)	(0.55-0.59)	0.64(0.55-0.70)	0.62(0.59-0.63)
6	Conductivity, mho x 10^{-4}			(88-107)	105(90-115)	(129-138)	123(110-130)	94(85-100)	63(50-80)	129(125-135)
7	pH[3]	6.5(6.3-6.6)	6.1(5.8-6.5)[b]	7.4(7.1-7.5)	6.9(6.4-7.8)	(6.7-6.8)	7.4(7.2-7.8)	(6.6-7.5)	6.9(5.9-7.3)	7.5(7.3-7.9)
8	Water, g/100 ml	93.2(92.7-93.6)	98.1(97.5-98.7)[b]	91.8(89.1-94.4)	90(87-95)	97.6	97.6		85.2	95.4(94-98)
9	Calcium, mEq/L	60(57-65)	0.6	12(10-14) (SP)	17(12-23)		10		5	(1-3)
10	Chloride, mEq/L	38(35-46)	156(145-170)[b]	43(28-57) (SP)	50	(175-185)	74(24-125)		24	92(42-120)
11	Magnesium, mEq/L			12	10	2	2		2	9(4-12)
12	Phosphorus, total			112(90-120)	82		19		355	66
13	Acid-soluble			57(28-94)	33				170	24
14	Inorganic	(1-2)	Trace	11	9		17		12	12
15	Lipid[5]	7(6-9)	(1-2)	6	9				29	6
16	Potassium, mEq/L	48(29-61)	5.1(4.7-5.5)[b]	23(17-27) (SP)	44(SP)		17		19	66(22-105)
17	Sodium, mEq/L	153(150-160)	159(155-165)[b]	117(100-135) (SP)	112				45	285(125-370)
18	Carbon dioxide, ml/100 ml	9(7-12)	5(3-6)[b]	54(43-74)	16		24		16	50
19	Trace metals	Zn+	Zn 14(5-22)		Fe 2				Fe 0.8; Cu 0.2; Zn 1.0	
20	Nitrogen, total	415(295-510)	210	915(560-1225)	755		165		875	615(335-765)
21	Protease			+	+				+	+
22	Fructose[6, 7]	16(trace-48)	0-30	224(90-520)	500(100-1100)	Trace	15(9-45)	(40-42)	500(275-?)	12(5-25)
23	Lipids, total	286(260-310)	(30-40)			180				
24	Cholesterol	80(62-105)	166(130-210)	80						
25	Sex hormones			♂+; ♀+	♂+		♂+			
26	Non-protein nitrogen	54(30-90	22	90(53-130)	48		55		57	22
27	Amino acids, free			+	+[8]					
28	Ammonia			2	2		1		2	1
29	Creatine				3		6			
30	Creatinine				12		4			0.3
31	Urea			72 (SP)	4		3		44	9
32	Uric acid			6	6				6	3
33	Ergothioneine			0-trace	0-trace				(0-trace)	15-20
34	Spermine	+		(20-250)	0		0			
35	Citric acid	(480-2700)	30	480(0-2300)	720(200-1700)	Trace	50(30-110)	(110-550)	137(110-260)	140(40-325)
36	Lactic acid			35(20-50)	29(15-43)		15		36	27
37	Ascorbic acid[9]	(0.5-0.6)	0.8(0.6-0.9)[b]	12.8(11.2-14.4)[b]	6.1(3.0-9.0)				5.1(1.6-8.1)	
38	"B-Vitamins"[10]			+	+					+
39	Nor-adrenalin			0.1-0.2	0.1					
40	Amylase	+	+	+	+	+				
41	Cholinesterase			+					++	++
42	Cytochrome[11]			+	+			+	+	+
43	β-Glucuronidase	++	+	++		+				
44	Hyaluronidase[11]			++	+++	+		+++		++
45	5'-Nucleotidase			+	+++				+	Low
46	Oxidases	Diamine		Diamine	Xanthine; L-amino-acid					
47	Phosphatase, acid, U/100ml[12]	(25,000-170,000)	(3-285)	219,000(54,000-420,000)	170(50-340)				+	Low
48	Phosphatase, alk., U/100ml[12]	Low	(0-107)	Low	390(100-3500)				High	
49	Proteases[13]	+	+	+		+				
50	Miscellaneous			Heptocosane	Sulfite 8.1					

/1/ Resting fluid. /2/ Pilocarpine stimulated. /3/ Buffalo semen: volume, 2.5(0.5-4.5); sperm no., 630(210-770); pH, 6.3(6.0-6.6)[b]. Fox semen: volume, 1.5(0.2-4.0); sperm no., 70(30-250); pH, (6.2-6.4. Goat semen: volume, 0.7(0.5-0.9)[b]; sperm no., 2600(650-7500); pH, 6.4(6.0-6.8)[b]. /4/ Values are respectively: total length; length x width x thickness of head; length of midpiece; length of tail. Other species: cat, 55; 5 x 3 x 1; 8; 43. Hamster, 155; 13 x 2 x 1; 50; 93. Monkey, 75; 6 x 4 x 2; 11; 59. Rat, 182; 18 x 2 x 1; (?); 164. /5/ Value x 25.8 = total phospholipid. Cephalin content of human prostatic fluid, 107(82-135); ether-insoluble content, 73(63-90). /6/ Prostatic fluid values are for total reducing sugar. Rabbit semen may contain up to 40 mg% glucose. Little, if any, glucose present in semen of other species. /7/ + in semen of goat, guinea pig, hamster, mouse, opossum, rat. /8/ Seminal plasma: alanine, 0.25; aspartic acid, 0.09; glutamic acid, 0.35; glycine, 0.09; histidine, 0.16; phenylalanine, 0.16; serine, 0.13. /9/ Guinea pig, prostatic fluid, 1.5(0.9-2.1)[b]; semen, 8.2(6.8-9.6)[b]. /10/ Man: choline, 70-2900; inositol, 100. Rat: choline, +. Swine: inositol, 450. Cattle: thiamine, 0.09 (0.03-0.15); riboflavin, 0.21(0.15-0.31); pantothenic acid, 0.37(0.23-0.47); niacin, 0.36(0.25-0.55); inositol, low. /11/ + in rat semen. /12/ U=units; one unit indicates activity for the liberation of one mg phenol from monophenylphosphate in one hr at 37°C; low in rat semen and prostatic fluid. /13/ Prostatic fluid and semen of man and dog contain fibrinogenase and fibrinolysin. Semen of man also contains aminopeptidase and pepsinogenase. Vesiculase is present in rat and guinea pig semen.

49. TEARS, PHYSICAL AND CHEMICAL CHARACTERISTICS: MAN

Values in parentheses are ranges.

	Constituent or Property	Value		Constituent or Property	Value		Constituent or Property	Value
1	Volume, g/16 hr	(0. 5-0. 67)	12	Vapor pressure, <> % NaCl	0. 93	23	Albumin, %	0. 39
2	Volume, σ (1.5-29 yr), mg/5 min	20+	13	Viscosity, γ	(1. 053-1. 405)	24	Globulin, %	0. 28
3	Volume, φ (12-29 yr), mg/5 min	13+	14	Solids, total, %	1. 8	25	Nitrogen, total, %	0. 16
4	pH	7. 47(7. 3-7. 7)	15	Dialyzable[1], %	0. 47	26	Non-protein N, %	0. 05
5	Conductivity, <> % NaCl	0. 9	16	Non-dialyzable, %	0. 91	27	Urea, %	0. 03
6	Freezing point depression, °C	-0. 551	17	Ash, %	1. 05	28	Ammonia (as NH_3), %	0. 005
7	Osmotic conc., <> % NaCl	0. 9	18	Bicarbonate, mEq/L	26	29	Glucose, true, mg/100 ml	2. 5
8	Osmotic pressure, Δ	0. 551	19	Chloride, mEq/L	128(118-138)	30	Sugar, reducing, mg/100 ml	6. 1
9	Osmotic pressure, <> mM NaCl	160(150-170)	20	Potassium, mEq/L	24. 1(20-28)	31	Lysozyme activity, units[2]	1440(800-2500)
10	Refractive index	1. 3369	21	Sodium, mEq/L	(142-147)	32	Ascorbic acid, mg/100 ml	0. 14
11	Surface tension, n	(0. 695-0. 749)	22	Protein, total, %	0. 67			

/1/ Other than NaCl. /2/ Viscosimetric units.

50. SALIVA, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES

Values are mg/100 ml of the unstimulated, mixed secretion of the salivary glands, unless otherwise indicated. Values in parentheses are estimate "d" of the 95% range (cf Introduction). S=paraffin stimulated.

	Constituent or Property	Value		Constituent or Property	Value		Constituent or Property	Value
	Man			Man (continued)			Dog	
1	pH	6. 7(5. 6-7. 6)	41	Glycine	1. 4(0. 5-3. 6)	80	pH	7. 5
2		7. 4(7. 2-7. 6) S	42	Histidine	(0. 35-2. 0) S	81	Solids, total	(440-1600)
3	Specific gravity	(1. 010-1. 020)	43	Isoleucine	(0. 2-0. 9) S	82	Ash	(290-610)
4	Freezing point, °C	(-0. 7 to -0. 34)	44	Leucine	(0. 02-0. 3) S	83	Calcium, mEq/L	(2. 9-6. 6)
5	Rate of flow, ml/min	0. 57(0. 1-1. 8)	45	Lysine	0. 77(0. 15-1. 5)	84	Chloride, mEq/L	(16. 3-70)
6		1. 9(0. 4-4. 8) S	46	Methionine	(0. 005-0. 01) S(?)	85	Phosphorus, total	(1. 2-3. 0)
7	Solids, total	580(385-860) S	47	Phenylalanine	(0. 6-2. 5) S	86	Potassium, mEq/L	(12. 3-23. 7)
8	Ash	(200-220)	48	Proline	(0. 35-1. 5) S		Goat[2]	
9	Calcium, mEq/L	3. 1(2. 3-5. 5)	49	Serine	0. 66(0. 33-1. 2)	87	pH	(8. 1-8. 3)
10		2. 8(1. 8-4. 6) S	50	Threonine	(0. 4-5. 6) S	88	Specific gravity	(1. 002-1. 065)
11	Carbon dioxide, vol %	14. 9(8. 2-25. 3)	51	Tyrosine	(0. 2-1. 0) S	89	Solids, total	1300
12		37. 1(19. 2-46. 0) S	52	Tryptophan	(0. 2-0. 9) S	90	Ash	520
13	Chloride, mEq/L	15. 5(8. 4-17. 7)	53	Valine	(0. 7-2. 2) S	91	Nitrogen, total	(5-22)
14		11. 8(8. 7-17. 7)	54	Glucose	19. 6(11. 3-28. 1)	92	Chloride, mEq/L	(2. 8-3. 4)
15	Cobalt, μg/100 ml	2. 4(0-12. 5) S	55	Citric acid	1. 0(0. 2-3. 1) S		Horse	
16	Copper, μg/100 ml	25. 6(10-47) S	56	Lactic acid, mEq/L	0. 17	93	pH	(7. 3-8. 6)
17	Fluoride, mEq/L	(0-0. 005)	57	Cholesterol	7. 5(3-15)	94	Specific gravity	(1. 001-1. 008)
18	Iodine, μg/100 ml	(0-350)	58	Ascorbic acid	0. 07(0-0. 37) S(?)	95	Solids, total[2]	1000
19	Magnesium, mEq/L	0. 6(0. 16-1. 06)	59	Biotin, μg/100 ml	0. 08	96	Ash	(100-500)
20	Phosphorus, total	19. 3	60	Choline	1. 6(0. 6-3. 6) S	97	Chloride, mEq/L^2	(0. 006-0. 06)
21	Phosphorus, inorganic	14. 9(7. 4-21. 1)	61	Cobalamin, μg/100 ml	0. 33(0. 15-0. 5) S(?)		Sheep	
22	Phosphorus, lipid	(0. 05-0. 20)	62	Folic acid, μg/100 ml	2. 4(0. 3-7. 5) S	98	pH	(8. 4-8. 7)
23	Potassium, mEq/L	14. 1(12. 8-16. 1)	63	Vitamin K, μg/100 ml	1. 5	99	Specific gravity[2]	(1. 009-1. 011)
24		18(14. 6-23. 8) S	64	Nicotinic acid, μg/100 ml	11. 5(2. 3-40. 9) S	100	Solids, total	1100
25	Sodium, mEq/L	17. 4(8. 7-23. 9)	65	Pantothenic acid, μg/100 ml	8. 8(1. 2-19) S	101	Ash	(700-900)
26		23. 9(7. 8-38. 3) S	66	Pyridoxine, μg/100 ml	0. 6(0. 1-1. 7) S	102	Nitrogen, total	(4-10)
27	Thiocyanate, mEq/L	(2. 6-5. 2)	67	Riboflavin, μg/100 ml	5. 0	103	Calcium, mEq/L	(0. 8-1. 5)
28	Nitrogen, total	90(36-125) S	68	Thiamine, μg/100 ml	(0. 2-1. 4) S	104	Chloride, mEq/L	(7. 0-12. 1)
29	Nitrogen, protein	64(23-90) S	69	Amylase, units/ml[1]	100(20-250)	105	Magnesium, mEq/L	(0. 5-0. 8)
30	Mucin	270(80-600) S	70	Cholinesterase, units/$L^{2,3}$	0. 33(0. 23-0. 43) S	106	Phosphorus, total, mM/L	(37-72)
31	Non-protein nitrogen	36. 4(8. 2-62) S	71	Esterase, total, units/$L^{2,4}$	0. 34(0. 12-0. 65) S	107	Phosphorus, inorg., mEq/L^2	52
32	Ammonia, mM/L	3. 5(0. 8-7. 1) S	72	Lipase, units/$L^{2,5}$	1. 42(0. 25-2. 58) S	108	Potassium, mEq/L	(6. 1-11. 8)
33	Creatinine	(0. 6-1. 09)	73	Lysozyme, units/L^2	670(250-1360) S		Swine	
34	Urea	8. 8(0-14) S	74	Phosphatase, acid, units/$L^{2,6}$	4. 23(2. 5-7. 7) S	109	pH	(7. 1-7. 4)
35	Uric acid	1. 5(0. 5-2. 9)		Cattle		110	Specific gravity[2]	(1. 002-1. 009)
36	Alanine	1. 2(0. 5-2. 9)	75	pH	(8. 1-8. 2)	111	Dry matter, g/100 ml[2]	(0. 3-4. 6)
37	Arginine	(1. 3-10) S	76	Specific gravity	(1. 002-1. 009)	112	Ash, g/100 ml[2]	(0. 1-0. 4)
38	Aspartic acid	0. 15(0. 13-0. 33)	77	Solids, total	880	113	Nitrogen, mM/L^2	(0. 04-0. 1)
39	Cystine	(0. 16-0. 45) S	78	Bicarbonate, mEq/L	91		Chicken	
40	Glutamic acid	1. 2(0. 5-1. 3)	79	Chloride, mEq/L	4. 3	114	pH	(6. 7-6. 9)

/1/ One unit of amylase is considered as the amount required to digest 5 ml of 1% soluble starch to the achromic point under the conditions of the test. /2/ Parotid gland secretion. /3/ β-Carbonaphthoxycholine substrate. /4/ β-Naphthyl acetate substrate. /5/ β-Naphthyl laurate substrate. /6/ Monosodium-β-naphthyl phosphate substrate.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part 1: GASTRIC JUICE

B=basal conditions (absence of all avoidable stimuli); C=caffeine stimulation; F=fasting normal value; FS=stimulated by food; H=histamine stimulation; HS=histamine and sham feeding stimulation; R=hunger juice; S=sham feeding, egg albumin and lean meats; U=fistulated.

	Constituent or Property		Value
	Man		
1	pH		(1.49-8.38)
2	Specific gravity		1.006(1.004-1.010)
3	Freezing point, °C	F	(-0.3 to -0.6)
4	Calcium, mEq/L	F	3.6(2.0-4.8)
5	Chloride, total, mEq/L	F	(78-159)
6		H	(131-170)
7	Potassium, mEq/L	F	11.6(6.4-16.6)
8	Sodium, mEq/L	F	49(18.7-70)
9	HCl, free, mEq/L	F	(0-115)
10		H	(78-135)
11	Acidity, total, mEq/L	F	(46-118)
12		H	(86-137)
13	Nitrogen, total, mg/ml	F	(0.91-2.18)
14		H	(0.73-1.34)
15	Nitrogen, α-amino acid	F	(5.6-8.4)
16		C	(7.2-14.4)
17	Protein	H	130
18	Alanine	F	(1.8-2.7)
19		C	(2.0-2.6)
20	Arginine	F	(3.3-3.6)
21		C	(3.5-5.0)
22	Aspartic acid	F	(1.7-2.3)
23		C	(1.6-2.5)
24	Cystine	F	(1.8-3.7)
25		C	(1.6-4.4)
26	Glycine	F	(1.3-1.6)
27		C	(1.2-2.1)
28	Glutamic acid	F	(2.0-3.2)
29		C	(2.6-4.7)
30	Histidine	F	(1.3-2.0)
31		C	(1.3-1.8)
32	Isoleucine	F	(0.7-1.4)
33		C	(2.3-2.5)
34	Leucine	F	(1.2-2.2)
35		C	(1.2-3.3)
36	Lysine	F	(1.4-1.8)
37		C	(1.3-1.6)
38	Methionin	F	(0.8-1.5)
39		C	(0.9-1.9)
40	Phenylalamine	F	(0.8-1.8)
41		C	(0.7-1.6)
42	Proline	F	(1.7-3.2)
43		C	(2.2-3.3)
44	Serine	F	(1.6-2.3)
45		C	(1.9-2.1)
46	Threonine	F	(1.5-2.5)
47		C	2.0
48	Tryptophan	F	(1.4-1.9)
49		C	(1.2-1.9)
50	Tyrosine	F	(1.0-1.1)
51		C	(0.9-1.3)
52	Histamine, μg/100 ml		(1.3-53.5)
53	Fucose		13.8
54	Glucose, mg/ml	F	(0.35-1.19)[1]
55		H	(0.33-1.12)[1]
56	Glucuronic acid		2.0
57	Hexosoamines		33
58	Hexoses, total		32
59	Sialic acid		7.31
60	Ascorbic acid	D	95(0.91-1.05)
61	Lysozyme, μg/ml		7.6(2.6-19.2)
62	Pepsin, hemoglobin units/hr	B	4100(0-8, 300)[2]
63	Pepsin, units/ml		(9.7-63)[3]
	Cat[4]		
64	Solids, total	FS	(170-650)
65	Ash	FS	(120-380)
66	Organic matter	FS	(48-265)
67	Calcium, mEq/L	FS	(1.7-5.3)
68	Chloride, mEq/L	FS	(156-166)
69	Phosphorus	FS	(0.16-0.55)
70	Potassium, mEq/L	FS	(11.5-13.6)
71	Sodium, mEq/L	FS	(12.2-56)
72	HCl, total, mEq/L	HS	(128-155)
73	free, mEq/L	HS	(97-122)
74	Nitrogen	HS	(10-41)
75	Histamine, μg/100 ml		(2.5-4.5)
76	Reducing power		(4-37)[5]
77	Pepsin, Mett units		(0-400)
	Cattle		
78	pH[6]		(2-4.1)

	Constituent or Property		Value
	Cattle (concluded)		
79	Specific gravity[7]		(1.002-1.003)
80	Acidity[7], mEq/L		(36-98)
81	Nitrogen[8], mg/100 g dry matter		2400
	Dog		
82	Specific gravity		(1.002-1.004)
83	Freezing point, °C		-0.59(-0.64 to -0.49)
84	Solids, total		(4.30-6.50)
85	Ash		133
86	Organic matter		294
87	Calcium, mEq/L		(0.95-3.3)
88	Chloride, total, mEq/L		173
89		S	123(98-143)
90	Phosphorus	R	0.27
91	Potassium, mEq/L		7.2
92		S	15.2(10.3-22.0)
93	Sodium, mEq/L		22
94		S	64(46-79)
95	HCl, free, mEq/L		150
96	Acidity, mEq/L	S	32(0-50)
97	Nitrogen, total		(50-80)
98	protein	S	(18-19.9)
99	non-protein (NPN)		(9.8-10.9)
100	total base		(5.4-6.6)
101	volatile base		(1.8-2.6)
102	non-volatile base		(3.6-4)
103	creatine + creatinine		(0.09-0.11)
104	histidine-arginine		(1.56-1.77)
105	humin bodies		(3.3-3.7)
106	lysine fraction		(1.9-2.2)
107	mono-amino fraction[8]		(0.7-1.02)
108	purine fraction		(0.10-0.11)
109	urea		(0.7-0.16)
110	Ammonia, mM/L		(1.2-4.6)
111	Arginine, moles[9]	S	(0.08-0.26)
112	Aspartic acid, moles[9]	S	(0.30-0.68)
113	Glutamic acid, moles[9]	S	(0.81-2.36)
114	Histidine, moles[9]	S	(0.04-0.08)
115	Isoleucine, moles[9]	S	(1.11-1.93)
116	Leucine, moles[9]	S	(1.30-3.58)
117	Lysine, moles[9]	S	(0.15-0.26)
118	Methionine, moles[9]	S	(0.13-0.22)
119	Phenylalanine, moles[9]	S	(0.06-0.44)
120	Proline, moles[9]	S	(0.05-0.21)
121	Serine, moles[9]	S	(0.43-0.76)
122	Threonine, moles[9]	S	1.00
123	Tryptophan, moles[9]	S	(0.03-0.04)
124	Tyrosine, moles[9]	S	(0.3-0.36)
125	Valine, moles[9]	S	(1.07-1.30)
126	Histamine, μg/L	S	(4-22)
127	Ascorbic acid		0.69(0.33-1.51)
128	Pepsin, units/ml	S	81(41-164)
	Goat		
129	Specific gravity		1.006
130	Acidity, mEq/L		(4-84)
	Horse		
131	HCl, mEq/L		(3.8-5.8)
	Sheep[6]		
132	pH	U	(1.05-3.6)
133	Freezing point, °C		(-0.56 to -0.61)
134	Dry matter, g/100 ml		(3.7-8.2)
135	Calcium, soluble, mEq/L		(190-335)
136	Chloride, mEq/L		(141-177)
137	Magnesium, soluble, mEq/L		(9.9-18.9)
138	Phosphorus, inorganic		(34-100)
139	Acidity, normal, mEq/L		86
	Swine		
140	Ash		(400-800)
141	Dry matter		(900-2400)
142	Chloride, mEq/L		78
143	Sodium, mEq/L		80
144	Acidity, mEq/L		100
145	Pepsin units[10]		34(4-38)
	Chicken		
146	Acidity, total, mEq/L	H	(120-180)
147	free, mEq/L	H	(80-150)
	Pigeon		
148	Acidity, total, mEq/L		(60-148)
149		H	(120-195)
150	free, mEq/L		(40-136)
151		H	(70-160)
152	Pepsin, Mett units	H	(0-36)

/1/ After hydrolysis. /2/ Substrate, lyophilized bovine hemoglobin powder. /3/ After test meal; substrate plasma protein. /4/ Determinations from one animal only. /5/ As glucose. /6/ Abomasal contents. /7/ Calf. /8/ Phosphotungstic acid filtrate. /9/ Avg. moles free amino acid per mole threonine. /10/ Method under investigation.

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part II: BILE

H = hepatic; G = gallbladder; ? = source uncertain.

	Constituent or Property		Value
	Man		
1	pH	H	7.5(6.2-8.5)
2		G	6.0(5.6-8.0)
3	Specific gravity	?	(0.998-1.062)
4	Freezing point, °C	?	-0.56
5	Specific conductivity[1]	?	(99-137)
6	Surface tension, dynes/cm	?	(39-41)
7	Viscosity, centipoises	?	(0.843-2.342)
8	Solids, total	H	2660(1000-4000)
9		G	11,140(4,700-16,500)
10	Dry matter	H	(2300-3300)
11		G	18,000
12	Inorganic matter	H	(200-900)
13		G	(500-1100)
14	Calcium, mEq/L	H	(2.0-4.5)
15		G	(5.0-7.0)
16	Chloride, mEq/L	H	(75-110)
17		G	(15-30)
18	Copper	?	(0.063-1.07)
19	Iodine[2]	?	(0.004-0.014)
20	Iodine[3]	?	0.05
21	Iron	?	(0.03-7.0)
22	Phosphorus, total	H	(9-22.3)
23	Potassium, mEq/L	H	4.9
24	Nitrogen, total	H	(67-92)
25		G	490
26	amino acid	H	5.4
27		G	(6.0-21.6)
28	peptide	H	14.0
29		G	(3.9-27.0)
30	rest	H	45.5
31		G	(68-94.0)
32	Base, total, mEq/L	H	(150-180)
33	Protein, total	H	275
34		G	(315-540)
35	Urea	H	23.6
36		G	(20-45)
37	Bile acids	H	(200-1830)
38		G	(1,500-10,000)
39	Bile pigment	H	(50-170)
40		G	(200-1500)
41	Bile salts	H	(650-1400)
42		G	11,500
43	Bilirubin	H	(20-200)
44		G	1000
45	Coproporphyrin	G	0.01
46	Mucin and pigment	H	610(430-930)
47		G	3420(1800-4300)
48	Glucides, total	H	(35-91)
49		G	240
50	Sugars, reducing	H	(17-52)
51		G	80
52	Cholesterol	H	120(80-170)
53		G	630(350-930)
54	Fat, neutral	H	110(40-300)
55		G	370(150-560)
56	Fatty acids	H	110(40-300)
57		G	(150-1090)
58	Lecithins	H	(100-575)
59		G	3500
60	Phospholipids	H	60(50-60)
61		G	200(180-220)
62	Phosphatides	H	(50-80)
63		G	(200-500)
64	Choline, total	H	(35-89)
65		G	550
	Cat		
66	pH	H	5.33
67	Chloride, mEq/L	H	12(10-13)
68		G	5(0-20)
69	Base, fixed, mEq/L	H	17.2(15.7-19.4)
70		G	27.4(26.1-31.8)
71	Bile pigment	H	119(52-218)
72		G	(238-1190)
73	Coproporphyrin	G	0.096
74	Alkaline phosphatase, units/100 ml[4]	G	(190-415)
	Cattle[5]		
75	pH	G	(6.74-7.47)
76	Solids, total	G	(8900-9040)
77	Ash and alkali	G	(1250-1300)
78	Bile acids, g/100 ml	G	(1550-1700)
79	Mucin	G	500
80	Cholesterol	G	60
81	Lipids, total	G	(100-160)
	Dog		
82	pH	H	(7.4-8.5)
83	Specific gravity	H	(1.008-1.015)
84	Dry matter	H	(2300-4500)
85		G	(11, 400-24, 600)
86	Calcium, mEq/L	H	7.3
87		G	26.1
88	Chloride, mEq/L	H	64
89	Iodine	?	(0.013-0.113)
90	Iron, mEq/100ml	?	(4-8)
91	Magnesium, mEq/L	H	3.6
92	Phosphorus, total	H	(10-15)
93		G	(87-280)
94	Potassium, mEq/L	H	6.6
95	Sodium, mEq/L	H	174
96	Nitrogen, total	H	(65-105)
97		G	(255-635)
98	Proteins, total	H	(130-210)
99		G	(190-520)
100	Allantoin content	?	18.9
101	Ammonia	?	(0.4-0.6)
102	Uric acid[6]	H	(0.37-0.50)
103	Bile salts	G	(500-2400)
104		G	(7,900-15,000)
105	Bilirubin[7]	H	(42-55)
106		G	(92-170)
107	Coproporphyrin	G	147
108	Glucides, total	G	(736-938)
109	Sugars, reducing	G	(64-72)
110	Cholesterol	H	(4-15)[8]
111		G	(80-100)
112	Fatty acids, total, g/100 ml	H	(0.18-0.27)
113		G	(1.6-5.0)
114	Lecithins, g/100 ml	H	(250-400)
115		G	(2250-7000)
116	Choline	H	(39-58)
117		G	(140-1110)
118	Alkaline phosphatase, units/100 ml[4]	H	(0-900)
	Goat		
119	Specific gravity	H	(1.004-1.010)
120	Dry matter	H	(2880-4720)
121	Ash	H	(480-760)
122	Bile pigment	H	126
	Goose		
123	Solids, total	G	21,950
124	Ash and alkali	G	2100
125	Bile acids	G	19,000
126	Mucin and pigment	G	3100
	Guinea Pig		
127	Solids, total	G	2160
128	Ash and alkali	G	100
129	Bile acids	G	780
130	Mucin	G	510
131	Lipids, total	G	140
	Horse		
132	Specific gravity	H	1.01
133	Bile pigment	H	33(12-38)
	Rabbit		
134	pH[6]	G	(6.4-6.7)
135	Specific gravity	G	1.048
136	Bicarbonate, mEq/L	H	46
137	Calcium, mEq/L[8]	H	(4-9.5)
138	Chloride, mEq/L	H	82
139	Iodine[2]	H	(0.004-0.014)
140	Iodine[3]	H	(0.026-0.069)
141	Magnesium, mEq/L	H	0.5
142	Phosphate, mEq/L	H	2.5
143	Potassium, mEq/L	H	5.7
144	Sodium, mEq/L	H	151
145	Sulfate, mEq/L	H	4.4
146	Ammonia (fresh bile)	H	(0.22-0.07)
147	Bile pigment	H	21.8
148		G	(87-131)
149	Sugars, reducing	H	20
150	Alkaline phosphatase, units/100 ml[4]	G	(56-302)
	Rat		
151	pH[6]	H	8.3
152	Specific gravity[8]	H	1.011

/1/ 30°C; per ohm cm. /2/ Fasting. /3/ Fed. /4/ King-Armstrong units; phenyl phosphate substrate; modified Bodansky method. /5/ Ox. /6/ Fistula bile. /7/ Values obtained by Van den Bergh method. /8/ Average.

Unless otherwise indicated values are mg/100 ml, those in parentheses are ranges.

Part II: BILE (Concluded)

H = hepatic; G = gallbladder; ? = source uncertain.

	Constituent or Property	Value		Constituent or Property	Value
	Rat (concluded)			Swine (concluded)	
153	Bilirubin, mg/100 ml/24 hr	H 8.3	169	Bile salts	G 7200
154	Cholesterol, mg/100 ml/24 hr	H 12.7	170	Bilirubin	? (32-62)
	Sheep		171	Coproporphyrin	G 0.077
155	pH	H (5.98-6.72)	172	Mucin, pigment, ash	G 1630
156	Bile pigment	H 108	173	Glucides, total	H (120-300)
157		G (50-110)	174	Sugars, reducing	H (37-150)
158	Coproporphyrin	G 0.077	175	Cholesterol	H (130-180)
	Swine		176		G 37
159	Solids, total	H (11,500-18,900)	177	Fatty acids, total	H (820-2000)
160		G 10,600	178		G (370)
161	Phosphorus, total	H (48-116)	179	Lecithins	H (1200-2900)
162		G 20.5	180		G 520
163	Nitrogen, total	H (370-480)	181	Lipids, total	G 1400
164		G 266	182	Choline, total	H (180-450)
165	Protein	H (280-410)	183		G 80
166		G 420		Chicken	
167	Bile acids	G 12,000	184	pH	H (6.0-6.2)
168	Bile salts	H (8,500-12,000)	185	Pigment	H 147

Part III: PANCREATIC JUICE

Unless otherwise indicated values are mg/100 ml secretion from pancreatic fistula; those in parentheses are ranges.

	Constituent or Property	Value		Constituent or Property	Value
	Man[1]			Man[1] (continued)	
1	pH	7-8	27	Lipase, units/100 ml	(300-2730)
2	Specific gravity	1.008	28	Phosphatase, Bodansky units/100 ml	(0.8-12.7)
3	Freezing point depression, °C	0.425		Dog	
4	Solids, total	(1240-1540)	29	pH	(7.1-8.2)
5	Solids, organic	(580-690)	30	Specific gravity	(1.007-1.014)
6	Ash	(520-860)	31	Freezing point depression, °C	(0.56-0.66)
7	Bicarbonate, mEq/L	(60-75)	32	Solids, total	(1400-6390)
8	Calcium, mEq/L	(2.2-3.2)	33	Solids, organic	480-2220
9	Chloride, MEq/L	(60-80)	34	Ash	840-970
10	Magnesium, mEq/L	0.3	35	Bicarbonate, mEq/L	(15-157)
11	Phosphorus[2], mEq/L	(0.026-1.22)	36	Calcium, mEq/L	(1.8-2.0)
12	Potassium, mEq/L	(4.1-5.6)	37	Chloride, mEq/L	(66-114)
13	Sodium, mEq/L	138	38	Magnesium, mEq/L	(0.2-1.4)
14	Sulfate, mEq/L	8.4	39	Phosphate, mM/L	(0.18-0.5)
15	Protein, total	(190-340)	40	Potassium, mEq/L	(3.0-7.0)
16	Albumin	60	41	Sodium, mEq/L	(151-162)
17	Globulin	40	42	Acid combining power, mEq/L	(58.8-80.4)[4]
18	Nitrogen	(590-1370)	43	Nitrogen, total	(280-936)
19	non-protein	(28-40)	44	protein	(75-84)
20	urea	(0.5-5.0)	45	non-protein	(18-84)
21	uric acid	0.2	46	Urea	(24-59)
22	Glucose	(8.5-18.0)	47	Glucose	25
23	Proteolytic enzymes, total[3]	(9.4-139)	48	Amylase, g maltose/ml juice	(23.5-47.5)[4]
24	Proteolytic enzymes, active[3]	(0.04-16.5)	49	Trypsin, mg tyrosine/ml juice	(407.5-2440)[4]
25	Trypsin, units/100 ml	(7.1-42.8)	50	Pseudocholinesterase, units/ml[5]	(420-1080)[4]
26	Amylase, units/100 ml	(6.4-31.1)			

/1/ Not listed are creatinine, uric acid, copper, SiO_2, and zinc (traces present); cobalt, iron, and nickel (absent). /2/ As $HPO_4^=$. /3/ Trypsin /4/ Secretin stimulated. /5/ One unit cholinesterase = amount of enzyme liberating 1 µl CO_2/min (0.06M acetylcholine perchlorate substrate).

Part IV: DUODENAL SECRETION

	Constituent or Property	Value		Constituent or Property	Value
	Man			Man (concluded)	
1	pH[1]	(5.8-7.6)	30	Cholesterol[3], mg/100 g	36.1(0-315)
2	Volume[2], ml/hr	30	31	Cholic acid, mg/100 g	(130-460)
3	Specific gravity	1.010	32	Bilirubin[3]	22.4(0-129)
4	Inorganic matter, mg/g	8	33	Icteric index[3]	59(17-299)
5	Solids, total, mg/g	15	34	Amylase[4], glucose units/hr	637
6	Bicarbonate (total CO_2), mEq/L	(8.4-41)	35	Lipase[4], fatty acid units/hr	179
7	Chloride, mEq/L	(64.2-110.3)	36	Phosphatase[3], units/100 ml	(10-30)
8	Potassium, mEq/L	(1.0-11.0)	37	Proteolytic enzymes, total[6]	(35-78)
9	Sodium, mEq/L	(84.8-143.4)	38	Active (trypsin)[6]	(16.4-48)
10	Nitrogen, mEq/L	41		Cat[7]	
11	Nitrogen, a-amino-	9.2	39	pH	(8.7-8.9)
12	Alanine	3.1	40	Specific gravity	1.009
13	Arginine	2.9	41	Solids, total, mg/g	13.3
14	Aspartic acid	3.0	42	Inorganic matter, mg/g	8.42
15	Cystine	4.5	43	Organic matter, mg/g	4.88
16	Glutamic acid	2.5		Dog	
17	Glycine	1.7	44	pH	(6.30-7.28)
18	Histidine	1.2	45	Specific gravity[7]	1.009
19	Isoleucine	1.1	46	Solids, total[7], mg/g	15.41
20	Leucine	1.2	47	Inorganic matter[7], mg/g	9.26
21	Lysine	2.2	48	Organic matter[7], mg/g	6.15
22	Methionine	2.0	49	Ash, mg/g	7.6-9.4
23	Phenylalanine	1.7		Goat[7]	
24	Proline	3.0	50	pH	(8.2-8.4)
25	Serine	2.0	51	Specific gravity	1.007, 1.008
26	Threonine	1.8	52	Solids, total, mg/g	14.6
27	Tryptophan	1.1	53	Inorganic matter, mg/g	7.73
28	Tyrosine	0.5	54	Organic matter, mg/g	6.83
29	Valine	1.9			

/1/ Duodenal contents. /2/ Spontaneous; after secretin σ = 181, φ = 126. /3/ Value for fasting adult. /4/ Duodenal contents, Lagerlöf method (starch solution substrate for amylase, tributyrin for lipase). /5/ Bodansky units (alkaline) di-sodiumphenyl phosphate substrate; value rises to 200 after fatty meal. /6/ Casein substrate. /7/ Brunner's glands secretion.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES (Concluded)

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part IV: DUODENAL SECRETION (Concluded)

	Constituent or Property	Value
	Rabbit[8]	
55	pH[8]	(8.6-9.0)
56	Specific gravity[7]	1.009
57	Solids, total, mg/g[7]	15.21
58	Inorganic matter, mg/g[7]	10.23
59	Organic matter, mg/g[7]	4.98
	Sheep	
60	pH[1]	(2.3-4.7)
61	Specific gravity	1.007
62	Dry matter, mg/g	(30-66)
63	Ash, mg/g	(3.9-6.5)

	Constituent or Property	Value
	Sheep (concluded)	
64	Acidity, total, mEq/L	(39-62)
65	Acid, volatile, mEq/L	(5-19)
66	Chloride, mEq/L	(109-135)
	Swine	
67	pH[8]	(8.4-8.9)
68	Specific gravity	(1.007-1.008)
69	Solids, total, mg/g[7]	11.80
70	Inorganic matter, mg/g[7]	6.81
71	Organic matter, mg/g[7]	4.99

/7/ Brunner's glands secretion. /8/ From fistula.

Part V: DIGESTIVE ENZYMES

AM = amylase (diastase); CA = carbonic anhydrase; EK = enterokinase; EP = erepsin, peptidases; SU = sucrase; LP = lipase, esterases; MT = maltase; NC = nuclease; PE = pepsin; PH = phosphatase; RI = ribonuclease; RN = rennin (chymosin); TR = trypsin; UR = urease; + = present; - = absent; ± = doubtful.

	Animal	En-zyme	T = tissue; S = secretion																									
			Salivary Glands		Esoph-agus		Stomach		Pan-creas		Small Intes-tine		Cecum and Colon				Salivary Glands		Esoph-agus		Stomach		Pan-creas		Small Intes-tine		Cecum and Colon	
			T	S	T	S	T	S	T	S	T	S	T	S			T	S	T	S	T	S	T	S	T	S	T	S
1		AM		+							+	±			59	Horse (con-cluded)	LP		+			+							
2		EK										+					PE									-		
3		EP		+					+	+	+	+			61		AM		+										
4		SU										+			62	Monkey	EK									+			
5		LP	+	+	+		+	+	+	+		±			63		EP		+										
6	Man	MT								+					64		AM		±						+		+		
7		PE					+	+							65		CA					+		+		+			
8		PH		+			+				+			+	66		EK										+		
9		RN						-[1]								67		ER									+	-		
10		TR								+					68	Rabbit	LP			+	+		+		±				
11		UR					+								69		PE			+					-				
12		AM		-					+			+			70		PH			+					+		+		
13		CA					+		+		+				71		TR							+		-			
14		EK									+				72		UR			+									
15		EP							+		±	±			73		AM		±					+	+	+			
16		SU										±			74		CA					+		+		+			
17	Cat	LP					+			+		-			75		EK									+			
18		MT							+						76		EP									+			
19		PE						+							77	Rat	LP					+		+					
20		PH	+				+		±		+			+	78		MT									+			
21		TR									+	-			79		PE					+							
22		UR					+								80		PH									+			
23		AM		±			+		+	+					81		TR						+						
24		EK										+			82		UR					+							
25		LP		+			+		+						83		AM		-				+	+					
26		PE			-			+			-				84		EK									+		-	
27	Cow	PH									+				85		LP		+			+		+					
28		RI							+						86	Sheep	PE			-		+							
29		RN					+[2]	±[2]							87		RN					+[2]							
30		TR							+	+					88		TR							+	+				
31		UR					+								89		UR					+							
32		AM		-				±	+	+		+		±	90		AM		+				-	+	+		+		
33		CA					+								91		EK									+	+		
34		EK									+	+			92		EP					+		+		-			
35		EP							+	+	+	+			93		SU									±			
36		SU										±			94		LP					+		+		+	±		
37		LP		+			+	+	+	+	+	±		+	95	Swine	PE					+	+			±			
38		MT							+						96		PH			-						+			
39	Dog	NC						+							97		RI						+						
40		PE			-			+							98		RN						±[2]						
41		PH									+				99		TR						+	+		-			
42		RI							+						100		UR					+							
43		RN						±[2]							101	Chick-en	AM		+						+		+		
44		TR							+	+		±			102		LP					+							
45		UR					+								103							+							
46		AM		-								+			104		AM		+										
47		EK										+			105		EP						+		+				
48		EP										-			106	Frog	MT						+		-				
49	Goat	SU										±			107		PE			+		+	+						
50		LP										±			108		TR						+						
51		RN						±[2]							109		UR					+							
52		TR										-			110	Fish (one or more vari-eties)	AM		±						+		±		
53		UR					-								111		LP					+			+				
54		AM		+										+	112		MT					+			-				
55	Guinea pig	EP							+		+				113		PE			+									
56		LP					+			+					114		RN					-[1]							
57		AM		±										+	115		TR						+						
58	Horse	EK										+																

/1/ In adult. /2/ Young only.

52. VARIOUS CELLS AND CELL PARTS: CHEMICAL COMPOSITION

DNA = desoxyribonucleic acid; RNA = ribonucleic acid.

	Tissue or Cell	Chemical Constituent	Value
		Man	
1	Liver, whole cell	DNA phosphorus, μμg/cell	1.0
2		RNA phosphorus, μμg/cell	4.3
3		Total nitrogen, μμg/cell	75.3
4	Nucleus	Nucleoprotein, %	42.59
5		Acidic protein, %	35.51
6		Total protein, "residual," %	4.7-7.5
7	Sperm	DNA phosphorus, μμg/sperm	0.31
8		RNA phosphorus, μμg/sperm	0.24
		Cattle	
	Liver, beef		
9	Whole cell	DNA phosphorus, μμg/cell	0.34
10		RNA phosphorus, μμg/cell	0.70
11	Nucleus	Total nucleic acid, % dry wt	27.5-30.7
12		DNA, μμg/nucleus	6.4
13		RNA, % dry wt	
	Heart, beef		
14	Nucleus	DNA, % dry wt	30.0
15		Total lipid, % dry wt	26.0
16		Phospholipid, % dry wt	15.7
17		Cholesterol, % dry wt	3.6
18		Fatty acid, % dry wt	6.5
	Sperm		
19	Whole cell	DNA, μμg/cell	2.82-3.4
20	Head	Total nucleic acid, % dry wt	48.0
21		DNA, μμg/head	3.3
22		Basic protein, % dry wt	28.7
23		Acidic protein, "lipo-," % dry wt	19.6
	Thymus, beef		
24	Nucleus	Total nucleic acid, % total N	31.0
25		Basic protein, % total N	35.0
26		Acidic protein, % total N	14.0
	Thymus, calf		
27	Whole cell	DNA phosphorus, mg/g fresh tissue	2.24-2.50
28		RNA phosphorus, mg/g fresh tissue	0.80-1.00
		Dog	
29	Liver, whole cell	Total lipid, % dry wt	17.2
30		Phospolipid, % dry wt	9.2
31		Cholesterol, % dry wt	1.07
32		Neutral fat, % dry wt	6.9
33	Nucleus	Total lipid, % dry wt	16.5
34		Phospholipid, % dry wt	10.7
35		Cholesterol, % dry wt	1.2
36		Fatty acid, % dry wt	4.6
37	Sperm, head	Total nucleic acid, % dry wt	55.3
38		Basic protein, % dry wt	25.0
39		Acidic protein, "lipo-," % dry wt	17.0
		Guinea Pig	
40	Liver, whole cell	Total protein, % dry wt	15.0
41	Mitochondria	Total N, % dry wt of fraction	10.0-12.0
42		Total lipid, % dry wt of fraction	25.0
43		Phospholipid, % dry wt of fraction	16.0
44	Microsome	Total N, % dry wt of fraction	9.15
45		Total lipid, % dry wt of fraction	40.0-51.0
46		Phospholipid, % dry wt of fraction	28.0-29.0
47		Phospholipid, % total lipid	58
		Mouse	
48	Liver, whole cell	DNA, mg/g fresh tissue	2.85
49		RNA, mg/g fresh tissue	9.0
50		RNA phosphorus, μ/mg N	28.0
51		Total protein, mg/g fresh tissue	126.3
52		Phospholipid, mg/g fresh tissue	30.1
53	Nucleus	DNA, %	27.0
54		RNA, %	3.4
55		Nucleoprotein, %	66.0
56		Phospholipid, %	3.4
57	Mitochondria	DNA, % total nucleic acid	5.6[1]
58		RNA, % total nucleic acid	16.8
59		RNA, % dry wt of fraction	3.7
60		Total N, %	23.5
61		Total N, % dry wt of fraction	12.1
62		Total lipid, % dry wt of fraction	27.4
63		Phospholipid, % of total lipid	56.6
64		Cholesterol[2], % of total lipid	12.6
65		Neutral fat, % of total lipid	30.8
66	Microsome	DNA, % total nucleic acid	14.2[1]
67		RNA, % total nucleic acid	52.4
68		RNA, % dry wt of fraction	9.1
69		Total N, %	23.1
70		Total N, % dry wt of fraction	10.3
71		Total lipid, % dry wt of fraction	35.1
72		Phospholipid, % of total lipid	62.7
73		Cholesterol[1], % of total lipid	14.5
74		Neutral fat, % of total lipid	22.8
		Rabbit	
75	Liver, whole cell	DNA phosphorus, mg/g fresh tissue	0.16-0.29
76		RNA phosphorus, mg/g fresh tissue	0.44-0.76
77	Mitochondria	Total nucleic acid, μ RNA P/mg N	70.0
78	Mitochondria (concluded)	Total N, % dry wt of fraction	10.5
79		Total lipid, % dry wt of fraction	29.6
80		Phospholipid, % dry wt of fraction	17.5
81	Microsome	Total nucleic acid, μg RNA P/mg N	80.0
82		Total N, % dry wt of fraction	9.0
83		Total lipid, % dry wt of fraction	43.4
84		Phospholipid, % dry wt of fraction	31.2
		Rat	
85	Liver, whole cell	DNA, mg/g fresh tissue	1.92
86		DNA, % dry wt	0.7-0.9
87		DNA phosphorus, mg/g fresh tissue	0.21-0.25
88		RNA, mg/g fresh tissue	5.88
89		RNA phosphorus, mg/g fresh tissue	0.79-1.10
90		RNA phosphorus, μg/mg N	27.0
91		Total protein, mg/g fresh tissue	129.0
92		Total lipid, % dry wt	15.2
93		Phospholipid, % dry wt	8.3
94		Cholesterol, % dry wt	2.4
95		Neutral fat, % dry wt	4.1
96	Nucleus	Total nucleic acid, % dry wt	11.4-27.5
97		DNA, % dry wt	4.4-30.0
98		DNA, μμg	6.0-11.1
99		DNA, mg/g fresh tissue	1.84
100		DNA, %	13.0
101		RNA, % dry wt	2.9-7.6
102		RNA, mg/g fresh tissue	0.64
103		Nucleoprotein, mg/g fresh tissue	20.0
104		Total lipid, % dry wt	10.5-18.13
105		Total lipid, %	3.2-10.0
106	Mitochondria	DNA, % total nucleic acid	11.7[1]
107		RNA phosphorus, μg/mg N	11.0
108		RNA, % total nucleic acid	19.0-46.0
109		Total N, %	23.0-38.6
110		Total protein, %	30.0-33.0
111		Total protein, mg/g fresh tissue	35.0-40.0
112		Total lipid, % dry wt of fraction	25.0-30.0
113		Phospholipid, % dry wt of fraction	66.0
114	Microsome	RNA, % total nucleic acid	50.0
115		Total nitrogen, %	11.0-20.0
116		Total protein, mg/g fresh tissue	19.0-21.0
117		Total lipid, % dry wt of fraction	40.0
		Fowl	
118	Erythrocytes, nucleus	Total nucleic acid, % dry wt	33.9-38.1
119		DNA, μμg/cell	2.34-2.49
120		DNA, %	45.0
121		RNA, % dry wt	0.7-2.5
122		Nucleoprotein, %	50.0-60.0
123		Acidic protein, %	33-40
124	Liver, nucleus	Total nucleic acid, % dry wt	29.4-31.2
125		DNA, μμg/nucleus	2.39-2.54
126		RNA, % dry wt	2.0-2.2
127	Sperm, nucleus	DNA, μμg/nucleus	1.26
		Fish	
128	Cod sperm, head	Total nucleic acid, % dry wt	30.3
129		RNA, % dry wt	0.3
	Herring sperm,		
130	head	Total nucleic acid, % dry wt	38.8-59.0
131		RNA, % dry wt	0-1.2
	Salmon sperm		
132	Head	Total nucleic acid, % dry wt	60.5
133	Whole cell	RNA, % dry wt	0.1
		Sea Urchin	
134	Sperm	DNA, μμg/cell	1.0
135		DNA, % dry wt	15.0
136	Ovum	DNA, μμg/cell	28.0
137		DNA, % dry wt	0.01
		Bacteria	
138	Staphylococcus	Total nucleic acid, % dry wt	11.57
139		DNA, % dry wt	2.82
140		RNA, % dry wt	8.75
141		Total N, % dry wt	13.95
142		Total protein, % dry wt	75.5
143	Bacillus anthracis	Total nucleic acid, % dry wt	4.35
144		DNA, % dry wt	1.15
145		RNA, % dry wt	3.20
146		Total N, % dry wt	10.0
147		Total protein, % dry wt	58.1
148	Escherichia coli	Total nucleic acid, % dry wt	12.84
149		DNA, % dry wt	3.72
150		RNA, % dry wt	9.12
151		Total N, % dry wt	14.61
152		Total protein, % dry wt	78.5
153	Salmonella typhosa	Total nucleic acid, % dry wt	13.12
154		DNA, % dry wt	4.40
155		RNA, % dry wt	8.72
156		Total N, % dry wt	14.40
157		Total protein, % dry wt	76.8

/1/ Contamination with nuclear material cannot be excluded. /2/ Unsaponifiable.

Part I: INSECTS

Values are for hemolymph and are mg per 100 ml, unless otherwise indicated.

	Constituent	Organism	Stage	Value
1	Albumin	Bee, honey (Apis mellifera)	Larva	3400
2		Beetle, water (Hydrophilus piceus)	Adult	800
3	Allantoin	Silkworm, Chinese oak (Antheraea pernyi)	Larva	10
4	Ammonia	Beetle, water (Hydrophilus piceus)	Adult	0
5		Silkworm, Chinese oak (Antheraea pernyi)	Larva	7
6	Bicarbonate	Armyworm, southern (Prodenia eridania)	Larva	7.8[1]
7		Fly, horse bot (Gasterophilus intestinalis)	Larva	90
8	Calcium	Armyworm, southern (Prodenia eridania)	Larva	37
9		Bee, honey (Apis mellifera)	Larva	14
10		Beetle, Japanese (Popillia japonica)	Larva	32
11		Butterfly, European cabbage (Pieris brassicae)	Larva	23-36
12		Cricket, Mormon (Anabrus simplex)	Adult	6[2]
13		Fly, horse bot (Gasterophilus intestinalis)	Larva	11.4
14		Moth, cynthia (Samia cynthia)	Pupa	36-38
15		Moth, pine hawk (Sphinx pinastri)	Pupa	30-33
16		Moth, spurge hawk (Deilephila euphorbiae)	Larva	41
17		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	33
18	Carbon dioxide	Bee, honey (Apis mellifera)	Larva	25-35[1]
19		Beetle, diving (Dytiscus marginalis)	Adult	7-53[1]
20		Beetle, water (Hydrophilus piceus)	Adult	55-90[1]
21		Fly, horse bot (Gasterophilus intestinalis)	Larva	40-130[1]
22		Silkworm (Bombyx mori)	Larva	9-11[1]
23	Chlorine	Armyworm, southern (Prodenia eridania)	Larva	120
24		Bee, honey (Apis mellifera)	Larva	120
25		Beetle, diving (Dytiscus marginalis)	Adult	225
26		Beetle, Japanese (Popillia japonica)	Larva	60-70
27		Butterfly, European cabbage (Pieris brassicae)	Larva	70-95
28		Fly, horse bot (Gasterophilus intestinalis)	Larva	53
29		Mosquito, northern house (Culex pipiens)	Larva	170
30		Mosquito, yellow fever (Aëdes aegypti)	Larva	180
31		Moth, goat (Cossus cossus)	Adult	27
32		Moth, pine hawk (Sphinx pinastri)	Pupa	58-63
33		Moth, spurge hawk (Deilephila euphorbiae)	Larva	49
34		Silkworm (Bombyx mori)	Adult	52
35	Cholesterol	Armyworm, southern (Prodenia eridania)	Larva	13
36		Bee, honey (Apis mellifera)	Larva	33
37	Citric acid	Fly, horse bot (Gasterophilus intestinalis)	Larva	65
38	Copper	Armyworm, southern (Prodenia eridania)	Larva	4.9
39		Fly, horse bot (Gasterophilus intestinalis)	Larva	0.5
40	Creatine	Bee, honey (Apis mellifera)	Larva	1.5
41	Fructose	Fly, horse bot (Gasterophilus intestinalis)	Larva	280
42		Moth, wax (Galleria mellonella)	Larva	0
43	Glycogen	Armyworm, southern (Prodenia eridania)	Larva	3.3
44		Bee, honey (Apis mellifera)	Larva	2.8
45		Fly, horse bot (Gasterophilus intestinalis)	Larva	85
46		Moth, wax (Galleria mellonella)	Larva	0
47		Silkworm (Bombyx mori)	Larva	50
48	Iron	Moth, spurge hawk (Deilephila euphorbiae)	Larva	5.8
49	Lactic acid	Armyworm, southern (Prodenia eridania)	Larva	Trace
50		Fly, horse bot (Gasterophilus intestinalis)	Larva	12-44
51	Lipids	Armyworm, southern (Prodenia eridania)	Larva	320
52		Bee, honey (Apis mellifera)	Larva	370-585
53		Fly, horse bot (Gasterophilus intestinalis)	Larva	137
54		Moth, spurge Hawk (Deilephila euphorbiae)	Pupa	830
55	Magnesium	Armyworm, southern (Prodenia eridania)	Larva	17
56		Bee, honey (Apis mellifera)	Larva	19-22
57		Beetle, Japanese (Popillia japonica)	Larva	47
58		Butterfly, European cabbage (Pieris brassicae)	Larva	50-110
59		Cricket, Mormon (Anabrus simplex)	Adult	1.7[2]
60		Moth, pine hawk (Sphinx pinastri)	Larva	56-72
61		Moth, spurge hawk (Deilephila euphorbiae)	Larva	43
86	Nitrogen, protein	Armyworm, southern (Prodenia eridania)	Larva	165
87		Bee, honey (Apis mellifera)	Larva	1100
88		Beetle, Japanese (Popillia japonica)	Larva	655-925
89		Beetle, water (Hydrophilus piceus)	Adult	500-720
90		Cricket, Mormon (Anabrus simplex)	Adult	695
91		Fly, horse bot (Gasterophilus intestinalis)	Larva	1720
92		Moth, spurge hawk (Deilephila euphorbiae)	Larva	825
93		Silkworm (Bombyx mori)	Pupa	415-940
94	Oxygen	Armyworm, southern (Prodenia eridania)	Larva	1.6-2.5[1]
95		Bee, honey (Apis mellifera)	Larva	0.5-0.8[1]
96		Beetle, diving (Dytiscus marginalis)	Adult	Trace
97		Beetle, water (Hydrophilus piceus)	Adult	0.1[1]
98	Phospholipid	Armyworm, southern (Prodenia eridania)	Larva	99
99	Phosphorus, total	Armyworm, southern (Prodenia eridania)	Larva	125
100		Bee, honey (Apis mellifera)	Adult	180-190
101		Cricket, Mormon (Anabrus simplex)	Adult	180
102		Fly, horse bot (Gasterophilus intestinalis)	Larva	110
103		Moth, spurge hawk (Deilephila euphorbiae)	Larva	12.0
104	Phosphorus, inorganic	Armyworm, southern (Prodenia eridania)	Larva	17.6
105		Bee, honey (Apis mellifera)	Larva	32
106		Beetle, diving (Dytiscus marginalis)	Adult	10.5
107		Cricket, Mormon (Anabrus simplex)	Adult	110
108		Fly, horse bot (Gasterophilus intestinalis)	Larva	12.5
109		Moth, cynthia (Samia cynthia)	Pupa	11
110		Moth, goat (Cossus cossus)	Larva	11.5
111		Moth, pine hawk (Sphinx pinastri)	Pupa	66
112		Moth, spurge hawk (Deilephila euphorbiae)	Larva	30
113	Potassium	Armyworm, southern (Prodenia eridania)	Larva	155
114		Bee, honey (Apis mellifera)	Larva	95
115		Butterfly, European cabbage (Pieris brassicae)	Larva	60-120
116		Cockroach, American (Periplaneta americana)	Adult	70[2]
117		Cricket, Mormon (Anabrus simplex)	Adult	60[2]
118		Fly, flesh (Calliphora erythrocephala)	Larva	145-155
119		Fly, horse bot (Gasterophilus intestinalis)	Larva	45
120		Moth, cynthia (Samia cynthia)	Pupa	160-170
121		Moth, emperor (Eudia pavonis)	Pupa	155
122		Moth, pine hawk (Sphinx pinastri)	Pupa	110-175
123		Silkworm (Bombyx mori)	Larva	155[2]
124		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	170
125		Worm, cabbage, imported (Pieris rapae)	Larva	290-310
126	Reducing substances, total, as glucose	Armyworm, southern (Prodenia eridania)	Larva	66
127		Bee, honey (Apis mellifera)	Larva	120-440
128		Beetle, Japanese (Popillia japonica)	Larva	225-285
129		Beetle, water (Hydrophilus piceus)	Adult	25-105
130		Cockroach, American (Periplaneta americana)	Adult	55-75
131		Fly, horse bot (Gasterophilus intestinalis)	Larva	355
132		Grasshopper, differential (Melanoplus differentialis)	Adult	36
133		Moth, spurge hawk (Deilephila euphorbiae)	Larva	125
134		Silkworm (Bombyx mori)	Larva	90-230
135	Sodium	Armyworm, southern (Prodenia eridania)	Larva	51
136		Bee, honey (Apis mellifera)	Larva	12-17
137		Beetle, Japanese (Popillia japonica)	Larva	35-50
138		Cockroach, American (Periplaneta americana)	Adult	245[2]
139		Cricket, Mormon (Anabrus simplex)	Adult	50[2]
140		Fly, flesh (Calliphora erythrocephala)	Larva	365
141		Fly, horse bot (Gasterophilus intestinalis)	Larva	400
142		Moth, cynthia (Samia cynthia)	Pupa	4.6-7.3
143		Moth, emperor (Eudia pavonia)	Pupa	7.0
144		Moth, Mediterranean flour (Ephestia kuehniella)	Larva	37-69

62	Nitrogen gas	Beetle, diving (Dytiscus marginalis)	Adult	1.8[1]	45	Sodium (concluded)	Silkworm (Bombyx mori)	Larva	32[2]
63		Beetle, water (Hydrophilus piceus)	Adult	1.9[1]	46		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	28
64	Nitrogen, total	Armyworm, southern (Prodenia eridenia)	Larva	570	47		Worm, cabbage, imported (Pieris rapae)	Larva	21-30
65		Bee, honey (Apis mellifera)	Larva	1450	48	Succinic acid	Fly, horse bot (Gasterophilus intestinalis)	Larva	240
66		Beetle, Japanese (Popillia japonica)	Larva	1150-1400	49	Sulfur	Armyworm, southern (Prodenia eridania)	Larva	44
67		Cricket, Mormon (Anabrus simplex)	Adult	1300	50		Fly, horse bot (Gasterophilus intestinalis)	Larva	9.7
68		Fly, horse bot (Gasterophilus intestinalis)	Larva	1850	51	Thiocyanate	Beetle (Dytiscus sp)	Whole	1.5-2.0
69		Moth, spurge hawk (Deilephila euphorbiae)	Larva	1200	52		Beetle, hydrophilid	Whole	0.75
70		Silkworm (Bombyx mori)	Adult	950-1250	53		Beetle, potato	Whole	3.5
71	Nitrogen, amino	Armyworm, southern (Prodenia eridania)	Larva	235	54		Beetle, stag (Lucanus cervies)	Whole	2.9
72		Bee, honey (Apis mellifera)	Larva	250-310	55		Armyworm, southern (Prodenia eridania)	Larva	5.2
73		Beetle, diving (Dytiscus marginalis)	Adult	135	56	Urea	Beetle, water (Hydrophilus piceus)	Adult	2.6
74		Beetle, Japanese (Popillia japonica)	Larva	230-245	57		Fly, horse bot (Gasterophilus intestinalis)	Larva	20.4
75		Beetle, water (Hydrophilus piceus)	Adult	40-80	58		Armyworm, southern (Prodenia eridania)	Larva	14.8
76		Cricket, Mormon (Anabrus simplex)	Adult	260	59		Bee, honey (Apis mellifera)	Larva	4-8
77		Fly, horse bot (Gasterophilus intestinalis)	Larva	95	60		Beetle, diving (Dytiscus marginalis)	Larva	18.0
78		Moth, goat (Cossus cossus)	Larva	235	61		Beetle, water (Hydrophilus piceus)	Adult	11-15
79		Moth, spurge hawk (Deilephila euphorbiae)	Larva	170	62	Uric acid	Fly, horse bot (Gasterophilus intestinalis)	Larva	2.2
80	Nitrogen, non-protein	Armyworm, southern (Prodenia eridania)	Larva	400	63		Moth, spurge hawk (Deilephila euphorbiae)	Larva	18-28
81		Bee, honey (Apis mellifera)	Larva	305-385	64		Silkworm (Bombyx mori)	Larva	5-15
82		Beetle, Japanese (Popillia japonica)	Larva	470-555	65		Silkworm (B. mori)	Pupa	7-15
83		Cricket, Mormon (Anabrus simplex)	Adult	605	66		Silkworm (B. mori)	Adult	13-15
84		Fly, horse bot (Gasterophilus intestinalis)	Larva	130	67	Zinc	Fly, horse bot (Gasterophilus intestinalis)	Larva	0.9
85		Moth, spurge hawk (Deilephila euphorbiae)	Larva	355	68		Silkworm (Bombyx mori)	Larva	1.1-1.3

/1/ Volume per cent, /2/ Serum only.

Part II: MOLLUSKS

	Constituent	Organism	Fluid[1]	Value[2]
1	Ammonia	Clam, soft shell (Mya arenaria)	U	21.5% tot. N excr.
2			MF	9% tot. NPN
3		Sea hare (Aplysia limacina)	U	33.5% tot. NPN
4			B	11.5% tot. NPN
5		Slug (Limax agrestis)	U	4.5% tot. NPN
6		Snail (Helix pomatia)	U	13.7% tot. NPN
7			B	11-18% tot. NPN
8	Calcium	Clam, hard shell (Venus mercenaria)	MF	9.5 mM/liter
9		Mussel (Anodonta cygnea)	B	8.4 mM/kg H_2O
10		Octopus, lesser (Eledone cirrosa)	B	9.8 mM/liter
11		Sea hare (Aplysia punctata)	BF	13.3 mM/liter
12	Carbon dioxide	Shell (Busycon spp)	B	13.5 mm CO_2 tens.
13	Chlorine	Clam, hard shell (Venus mercenaria)	MF	515 mM/liter
14		Mussel (Anodonta cygnea)	B	11.7 mM/kg H_2O
15		Octopus, lesser (Eledone cirrosa)	B	460 mM/liter
16		Sea hare (Aplysia punctata)	BF	625 mM/liter
17	Cholesterol	Abalone, red (Haliotus refuscens)	BF	1.6 mg/100ml
18	Copper	Shell (Busycon canaliculatum)	B	9-16 mg/100ml
19		Snail (Helix pomatia)	B	6-12 mg/100ml
20	Iron	Oyster (Ostrea spp)		19-55 mg/kg meat
21	Magnesium	Clam, hard shell (Venus mercenaria)	MF	25 mM/liter
22		Mussel (Anodonta cygnea)	B	0.2 mM/kg H_2O
23		Octopus, lesser (Eledone cirrosa)	B	48.7 mM/liter
24		Sea hare (Aplysia punctata)	BF	53 mM/liter
25	Nitrogen	Octopus (Octopus vulgaris)	HC	16% comp.
26		Shell (Busycon canaliculatum)	HC	16% comp.
27		Shell (Helix pomatia)	HC	15% comp.
28	Oxygen	Octopus (Octopus spp)	HC	22% comp.

	Constituent	Organism	Fluid[1]	Value[2]
29	Phospholipid	Snail (Helix pomatia)	B	0.7 mg/100ml
30	Potassium	Clam, hard shell (Venus mercenaria)	MF	7.4 mM/liter
31		Mussel (Anodonta cygnea)	B	0.5 mM/kg H_2O
32		Octopus, lesser (Eledone cirrosa)	B	11.6 mM/liter
33		Sea hare (Aplysia punctata)	BF	12.0 mM/liter
34	Protein	Clam, soft shell (Mya arenaria)	B	0.09 g/100ml
35		Mussel (Anodonta spp)	B	0.07 g/100ml
36		Sea hare (Aplysia spp)	B	0.28 g/100ml
37		Snail (Helix spp)	B	2.8 g/100ml
38	Sodium	Clam, hard shell (Venus mercenaria)	MF	440 mM/liter
39		Mussel (Anodonta cygnea)	B	15 mM/kg H_2O
40		Octopus, lesser (Eledone cirrosa)	B	390 mM/liter
41		Sea hare (Aplysia punctata)	BF	590 mM/liter
42	Sulfur as SO_4	Clam, hard shell (Venus mercenaria)	MF	25.8 mM/liter
43		Mussel (Anodonta cygnea)	B	0.8 mM/kg H_2O
44		Octopus, lesser (Eledone cirrosa)	B	18.5 mM/liter
45	Urea	Octopus (Octopus vulgaris)	U	8-9% tot. NPN
46			B	5% tot. NPN
47		Oyster (Gryphoea angulata)	MF	3.2% tot. NPN
48		Sea hare (Aplysia limacina)	U	8.7% tot. NPN
49		Snail (Helix pomatia)	U	20% tot. NPN
50			B	13-36% tot. NPN
51	Uric Acid	Octopus (Octopus vulgaris)	U	1.4% tot. NPN
52		Sea hare (Aplysia limacina)	U	4.6% tot. NPN
53			B	2.6% tot. NPN
54		Snail (Helix pomatia)	U	10.7% tot. NPN
55	Zinc	Clams, various	W	77 mg/kg
56		Oyster (Ostrea spp)	W	26-2300 mg/kg

/1/ B = blood; BF = body fluid; HC = hemocyanin; MF = mantle fluid; U = urine; W = whole organism. /2/ Comp. = composition; excr. = excreted; mM = millimole; NPN = non-protein nitrogen; tens. = tension; tot. = total.

Part III: A PARASITIC NEMATODE

Perivisceral fluid of the roundworm of swine (Ascaris lumbricoides). Values are millimoles per liter, unless otherwise indicated; those in parentheses are ranges.

	Constituent	Value		Constituent	Value		Constituent	Value
1	Ammonia	0.75	7	Hematin	0.03 (0.01-0.04)	13	Phospholipid	123 (120-130) mg/100ml
2	Ascorbic acid	(0.04-0.07)	8	Iron	0.13 (0.08-0.21)	14	Phosphorus, total	(11.2-12.3)
3	Ash (sulfate)	0.96 (0.7-1.1) g/100ml	9	Magnesium	4.9 (4.5-5.8)	15	Potassium	24.6 (16.4-36.6)
4	Calcium	5.9 (4.7-9.0)	10	Nitrogen, protein	0.69 (0.65-0.73) g/100ml	16	Sodium	130 (120-140)
5	Chloride	52.7 (46-57)	11	Nitrogen, non-protein	50 (47-53) mg/100ml	17	Urea	0.17
6	Glucose	1.2 (1.1-1.4)	12	Nitrogen, amino	(10-20)	18	Zinc	0.14 (0.13-0.19)

Methods used in pH determinations are given in the footnotes. Values in parentheses are ranges of values and correspond to estimate "d" of the 95% range (cf Introduction).

	Organism and Part	pH
	Animals	
	PROTOZOA	
	Actinosphaerium eichorni	
1	Digestive vacuole (before food)	(6.6-6.9)[1]
2	During digestion	4.3[1]
3	After digestion	5.4[1]
	Amoeba dubia	
4	Cytoplasm	6.8(6.4-7.2)[1]
5	Vacuole	7.6[2]
	A. limax	
6	Exoplasm	7.2[2]
7	Pseudopodia, resting	(7.0-7.2)[2, 3]
8	After movement	6.8[4, 5]
	A. polypodis	
9	Hyaline cytoplasm	(7.2-7.3)[1]
	A. proteus	
10	Cytoplasm	6.9(6.8-7.0)[1]
11	Resting	(6.7-7.3)[6]
12	After movement	(6.5-7.0)[2]
	Entamoeba coli	
13	Cytoplasm	6.7(6.6-6.8)[6]
14	Endoplasm, resting	6.5[6]
15	After movement	(6.5-7.0)[6]
16	Exoplasm, resting	6.8[6]
17	After movement	(6.5-7.0)[6]
18	Nucleus	7.0[6]
	E. histolytica (Human)	
19	Cytoplasm	7.0[7]
20	Endoplasm, resting	6.5[6]
21	After movement	(6.8-6.3)[6]
	Leishmania donovani	
22	Cytoplasm	(6.4-6.8)[2]
	Nyctotherus cordiformis	
23	Cytoplasm	(6.8-7.0)[1]
24	Macronucleus	6.0[2]
25	Pulsating vacuole	7.2(7.0-7.4)[2]
	Paramecium caudatum	
26	Cytoplasm (herbivosis)	6.8(6.7-6.9)[2]
27	Digestive vacuole	4.0(4.0-7.6)[2]
	Trichomonas vaginalis	
28	Cytoplasm	(5.5-6.8)[2]
	Vorticella spp	
29	Digestive vacuole	4.5(4.5-7.0)[2]
30	Resting	5.0[2]
31	After contracting	3.5[2]
	PORIFERA	
	Aplysinidae spp	
32	Body substance	<6.0[4, 8]
33	Cortex	8.5[4, 8]
34	Choanocome	<7.0[4, 8]
	Mellita sexiesperforata	
35	Integument	7.5[4, 8]
	COELENTERATA	
	Aglantha digitalis, medusa	
36	Umbrella epithelium	7.0[2]
	Clytia johnstoni, medusa	
37	Tissue	6.6[2]
	Hydra fusca	
38	Cortical protoplasm	(7.5-7.6)[6]
39	Inner protoplasm	6.8(6.7-7.0)[6]
40	Nucleus	<6.6[6]
41	Nematocyst cell, cytoplasm	7.1(7.0-7.2)[6]
42	Pigment cell, cytoplasm	(7.4-7.6)[6]

	Organism and Part	pH
	Animals (continued)	
	MOLLUSCA (concluded)	
	Chromodoris zebra	
81	Nucleus of integument	>5.6(5.6-7.6)[8]
	Mactra solidissima	
82	Cytoplasm	6.8(6.6-7.0)[1]
83	Nucleus	7.4(7.2-7.6)[1]
	Octopus vulgaris	
84	Liver cells	7.0[11]
	Patella picta	
85	Muscle tissue	(5.6-6.0)[10]
	Pecten yessoensis	
86	Ciliated cells	7.0[2]
	Sepia officinalis	
87	Liver cells	6.0[11]
	Trochocochlea lineata	
88	Cytoplasm	5.2[10]
	ARTHROPODA (Crustacea)	
	Astacus fluviatilis	
89	Hepatopancreas	(6.0-6.3)[11]
	Carcinus maenas	
90	Hepatopancreas	6.1[11]
91	Muscle fibers	6.8[11]
	Chondracanthus lophii	
92	Egg, cytoplasm	5.0[10]
	Maja squinado	
93	Egg, cytoplasm	5.0[10]
	Platycarcinus pagurus	
94	Hepatopancreas	(5.9-6.8)[11]
	Portunus puber	
95	Hepatopancreas	6.1[11]
	ARTHROPODA (Insecta)	
	Chironomus plumosus, larva	
96	Salivary gland cell, cytoplasm	(7.1-7.2)[2, 6]
97	Vacuole	6.9(6.8-6.9)[2, 6]
	Dytiscus marginalis	
98	Striated muscle cells	6.7(6.7-6.8)[6]
	UROCHORDATA	
	Ascidia mentula	
99	Cytoplasm	5.0[10]
100	Nucleus	(7.2-7.5)[10]
101	Unfertilized egg, cytoplasm	6.6(6.5-6.7)[1]
102	Vacuole	5.0[2]
	Fragarium elegans	
103	Tissue	(5.6-6.0)[10]
	Styelopsis spp	
104	Cytoplasm	4.7[10]
	PISCES	
	Fundulus heteroclitus	
105	Cytoplasm	6.4(6.1-6.8)[11]
106	Striated muscle cells	(6.6-6.8)[11]
	AMPHIBIA	
	Rana esculenta	
107	Histiocytes, cytoplasm	(6.0-7.2)[2, 12]
	R. pipiens	
108	Muscle fibers (in NaCl)	6.0[1]
109	(in $NaHCO_3$)	8.4[1]
	R. temporaria	
110	Unfertilized egg, cytoplasm	6.0[10]
111	Ovarian egg cell tissue	7.2[11]
112	Fertilized egg, cytoplasm	8.5[11]
	Salamander spp	
113	Muscle fibers	6.6[11]

	Organism and Part	pH
	Animals (concluded)	
	Ovary, eggs (concluded)	
165	Stromal cells	6.8(6.7-6.9)[6]
166	Pancreas, parenchyma	(7.2-7.4)[6]
167	Islet cells	(6.6-6.9)[6]
168	Spleen	6.7(6.5-7.0)[2]
	Mouse (Mus musculus)	
169	Bone	6.8(6.5-7.2)[2]
170	Lymph node	<6.2[6]
171	Muscle, striated	6.0[1]
172	Spleen	6.7(6.5-7.0)[2]
	Rabbit (Oryctolagus cuniculus)	
	Alimentary canal	
173	Stomach, chief cells	6.8[1]
174	Parietal cells	6.7[1]
175	Duodenum	6.3[11]
176	Ileum	6.9[11]
177	Cecum	7.1[11]
178	Large intestine	7.0[11]
179	Liver, peripheral cells	(7.1-7.5)[6]
180	Central cells	(6.7-7.0)[6]
181	Kupffer cells	(6.4-6.5)[6]
182	Pancreas, pareochyma	(7.2-7.4)[6]
183	Islets	(6.6-6.9)[6]
184	Uterus, non-pregnant	6.8[14]
185	Involuting	6.6[14]
	Rat (Rattus rattus)	
	Alimentary canal	
186	Stomach, chief cells	6.8(6.6-7.0)[6]
187	Parietal cells	6.5(6.4-6.6)[6]
188	Duodenum	(6.8-7.0)[6]
189	Jejunum	7.3[6]
190	Ileum	(7.4-7.6)[6]
191	Large intestine	(7.4-7.6)[6]
192	Bone	6.8(6.5-7.3)[2]
193	Liver, total tissue	6.9(6.8-7.0)[15]
194	Peripheral cells	7.3(7.1-7.5)[6]
195	Central cells	6.8(6.7-7.0)[6]
196	Kupffer cells	6.4(6.4-6.5)[6]
197	Ovary, eggs	7.8(7.5-7.8)[6]
198	Follicular cells	7.1(7.0-7.3)[6]
199	Stromal cells	6.8(6.7-6.9)[6]
	Plants	
	MICROORGANISMS	
200	Brucella abortus	(7.2-7.6)[2]
201	Eberthella typhi	(7.2-7.6)[2]
202	Escherichia coli	(7.2-7.6)[2]
203	Klebsiella pneumoniae	(7.2-7.6)[2]
204	Saccharomyces cerevisiae	(6.1-6.3)[2]
205	Staphylococcus spp	(6.1-6.3)[2]
206	Streptococcus spp	(6.1-6.3)[2]
	THALLOPHYTA (Algae)	
	Laminaria digitata	
207	Stipe, outer cortex, mature	(4.8-5.3)[16]
208	Young	5.9[16]
209	Stipe, inner cortex	(6.4-6.8)[16]
210	Medulla, mature	(4.8-5.2)[16]
211	Young	(5.9-6.2)[16]
	Nitella clavata	
212	Cytoplasm	(5.0-6.2)[2, 11]
	THALLOPHYTA (Fungi)	
	Agaricus campestri	
213	Stipe, pileus and hymeneal layers	5.9[16]

43	Digestive cell, 3 day fast	7.2[6]
44	After ingestion	<6.1[6]
	Sagartia parasitica	
45	Tissue	(5.6-6.0)[9]
	Sertularia pumila	
46	Tissue	5.2[9]
	Tiara pileata, medusa	
47	Mantle canal and tentacle	(6.2-6.4)[2]
48	Umbrella	7.2[2]
	ROTIFERA	
	Rousselte spp	
49	Cytoplasm	(5.6-6.0)[10]
	ECHINODERMATA	
	Arbacia equituberculata	
50	Cytoplasm	(5.0-5.2)[11]
	A. punctulata	
51	Unfertilized egg, cytoplasm	6.8(6.6-7.0)[1]
52	Pigment cells	5.3(5.0-5.6)[5]
	Asterias glacialis	
53	Unfertilized egg, cytoplasm	7.2[1]
54	Oocyte, cytoplasm	7.2(7.0-7.4)[1]
	A. rubens	
55	Unfertilized egg, cytoplasm	6.7(6.6-6.8)[1]
56	Nucleus	7.5(7.4-7.6)[1]
57	Fertilized egg, cytoplasm	6.7(6.5-6.9)[1]
58	Cortical protoplasm	5.0[2]
59	Inner protoplasm	7.6[2]
	Echinocardium cordatum	
60	Unfertilized egg, cytoplasm	6.6[1]
	Ophiura lacertosa	
61	Unfertilized egg, cytoplasm	6.7(6.6-6.8)[1]
	Paracentrotus lividus	
62	Cytoplasm	7.2(7.0-7.4)[1]
63	Unfertilized egg, cytoplasm	6.6[1]
64	Nucleus	7.2[1]
	Psammechinus miliaris	
65	Cytoplasm	5.2[10]
	ANNELIDA	
	Arenicola ciaparedii	
66	Nucleus	(7.2-7.5)[10]
	Lumbricus spp	
67	Ectoderm, central protoplasm	7.3[6]
68	Muscle cells	6.7[6]
	Nereis limbata	
69	Cytoplasm	(5.6-6.0)[10]
	Platydella soleae	
70	Salivary gland tissue	(5.6-6.0)[10]
71	Clitellum tissue	(5.6-6.0)[10]
	Sabellaria alveolata	
72	Cytoplasm	5.0[10]
73	Nucleus	6.0[10]
74	Unfertilized egg, cytoplasm	6.6(6.5-6.7)[1]
	Spirographis spp	
75	Cytoplasm	6.0[10]
76	Chordoid cells	7.2[2]
77	Cytoplasm, tentacles	7.2[2]
78	Vacuole	6.6[2]
	MOLLUSCA	
	Anodonta cygnea	
79	Liver cells	6.8[11]
	Aplysia limacina	
80	Cytoplasm	(7.0-7.8)[10]
	Triton marmoratus	
81	Unfertilized egg, cytoplasm	7.2(7.2-7.3)[2]
	T. taeniatus	
82	Outer cells, blastula	(7.6-7.8)[11]
83	Embryonic yolk	(6.9-7.0)[11]
	AVES	
	Pigeon (Columba spp)	
84	Flight muscle tissue	(5.5-5.9)[11]
85		(6.1-6.8)[13]
86	Leg muscle tissue	(5.5-6.1)[11]
87		(6.7-7.4)[13]
	MAMMALIA	
	Cat (Felis catus)	
	Alimentary canal	
88	Stomach, parietal cells	(6.9-7.0)[6]
89	Chief cells	(6.4-6.5)[6]
90	Duodenum	(6.8-7.0)[6]
91	Jejunum	(7.2-7.3)[6]
92	Ileum	(7.4-7.6)[6]
93	Large intestine	(7.4-7.6)[6]
94	Cartilage, bronchial	(6.6-6.9)[6]
95	Kidney tissue	7.0[11]
96	Tubules	(6.7-7.0)[6]
97	Reticular cells	6.5(6.4-6.6)[6]
98	Liver tissue	(6.8-7.0)[13]
99	Peripheral cells	(7.3-7.5)[6]
100	Central cells	(6.7-7.0)[6]
101	Kupffer cells	(6.4-6.5)[11]
102	Muscle, cardiac	(6.8-7.0)[11]
103	Ovary, eggs	(7.5-7.8)[6]
104	Follicular cells	7.1(7.0-7.3)[6]
105	Stromal cells	6.8(6.7-6.9)[6]
106	Pancreas, parenchyma	(7.2-7.4)[6]
107	Islet cells	(6.6-6.9)[6]
108	Skin, muscle epithelium	(7.3-7.5)[6]
109	Basal epithelium	(6.8-6.9)[6]
110	Horny epithelium	6.2[6]
111	Fetus, born	6.8[14]
	Dog (Canis familiaris)	
112	Cardiac muscle	6.9(6.8-7.0)[15]
113	Striated muscle	(6.4-6.7)[11]
	Hamster (Cricetus spp)	
114	Testes, cortical protoplasm	7.4[6]
115	Central protoplasm	6.8[6]
116	Spermatozoids	(6.4-7.4)[6]
117	Interstitial cells	6.7(6.6-6.8)[6]
	Guinea pig (Cavia porcellus)	
	Alimentary canal	
118	Cartilage, chondrocytes	(6.6-6.8)[6]
119	Stomach, parietal cells	(6.9-7.1)[6]
120	Chief cells	(6.5-6.6)[6]
121	Duodenum	(6.8-7.0)[6]
122	Jejunum	(7.2-7.3)[6]
123	Ileum	(7.4-7.6)[6]
124	Large intestine	(7.4-7.6)[6]
125	Kidney, tubules	(6.8-7.0)[6]
126	Liver, total tissue	6.9(6.8-7.0)[13]
127	Peripheral cells	7.3(7.1-7.5)[6]
128	Central cells	6.8(6.7-7.0)[6]
129	Kupffer cells	6.4[6]
130	Ovary, eggs	(7.5-7.8)[6]
131	Follicular cells	7.1(7.0-7.3)[6]

	THALLOPHYTA (Fungi) (concluded)	
	Amanita muscaris	
214	Stipe, pileus and hymeneal layers	6.2[16]
	Coprinus stramentarius	
215	Stipe	6.2[16]
	Hypholoma fasciculare	
216	Stipe	(4.8-5.2)[16]
	BRYOPHYTA	
	Polytrichum commune	
217	Epidermal walls	<3.4[16]
218	Cortex	(4.0-4.4)[16]
	PTERIDOPHYTA	
	Dryopteris filix mas	
219	Rachis and rhizome	(4.8-5.2)[16]
	Equisetum maximum	
220	Rhizome, endodermis	(4.8-5.2)[16]
221	Phloem	5.9[16]
	SPERMATOPHYTA (Gymnosperma)	
	Pine, Austrian (Pinus nigra austriaca)	
222	Stem, epidermal and xylem walls	<3.4[16]
223	Mesophyll	(4.8-5.2)[16]
	SPERMATOPHYTA (Angiosperma)	
	Broad bean (Vicia faba)	
224	Stem, epidermis	5.6[16]
225	Cortex, outer	(4.8-5.9)[16]
226	Pericycle	(4.8-5.2)[16]
227	Pith	(5.6-5.9)[16]
228	Roots, exodermis	(4.8-5.2)[16]
229	Phloem	(4.8-5.2)[16]
230	Cambium	(4.8-5.2)[16]
231	Leaves, epidermis	(4.8-5.6)[16]
232	Chlorenchyma	(4.8-5.9)[16]
233	Flowers, epidermis	(4.8-5.2)[16]
234	Anthers	(5.6-5.9)[16]
235	Pollen	(4.8-5.6)[16]
236	Seeds, plumule	(4.8-5.2)[16]
	Potato (Solanum tuberosum)	
237	Stems, epidermis	(4.8-5.2)[16]
238	Cortex, outer	(4.8-5.9)[16]
239	Pericycle	5.6[16]
240	Roots, pilleferous layer	5.6[16]
241	Phloem	5.6[16]
242	Cambium	5.9[16]
243	Tuber, ssp	(4.8-5.2)[16]
244	Cytoplasm	5.9[16]
245	Leaves, epidermis	5.6[16]
246	Chlorenchyma	5.9[16]
	Sunflower (Helianthus annuus)	
247	Stems, epidermis	(4.0-4.4)[16]
248	Cortex, outer	(4.8-5.8)[16]
249	Pericycle	(4.8-5.8)[16]
250	Roots, exodermis	(4.0-5.2)[16]
251	Phloem	(4.8-5.2)[16]
252	Cambium	(4.8-5.2)[16]
253	Leaves, epidermis	(4.0-4.4)[16]
254	Chlorenchyma	(4.8-5.8)[16]
255	Flowers, epidermis	(<3.4-4.4)[16]
256	Anthers	(5.6-5.9)[16]
257	Pollen	(4.8-5.2)[16]
258	Seeds, plumule	(4.8-5.2)[16]

/1/ Microinjection of liquid indicators. /2/ Vital staining. /3/ Micropipette method. /4/ Natural indicators. /5/ Spectrophotometric determination. /6/ Microinjection of solid indicator particles. /7/ Tissue culture method. /8/ Gas cell apparatus. /9/ Data on method not available. /10/ Crushed cells in solution. /11/ Electrometric methods. /12/ Ameboid movement with phagocytosis of Indis ink. /13/ Haas colorimetric method. /14/ Perfusion of tissues, buffering capacity. /15/ Tissue brei. /16/ Range indicator method of Small.

55. VERTEBRATE TISSUES AND ORGANS: CHEMICAL COMPOSITION

The subject matter of this table is probably the most controversial, and the values therein the most widely variable, of any table in the Handbook. Data from many contributors and hundreds of literature references have gone into its make-up, and each value or range may represent a "reconciliation" of several divergent values obtained by almost as many divergent analytical methods from a number of domestic and foreign laboratories. Therefore, it has been almost impossible to devise a system for presenting an accurate mean value or "95% range" for any component listed. Some of the values are means, some single observations, others ranges of means, and still others ranges of extremes. Consequently the user of this table is warned that these values are to be considered only as "yardsticks," and are not subject to statistical manipulation or conclusive interpretation.

Part I: NERVE TISSUE

Section 1: Man, Cat, Cattle, Dog, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; PN = peripheral nerve.

Component	Man				Cat			Cattle			Dog			Rabbit		Rat	
	Whole Brain	Spinal Cord	Gray Matter[1]	White Matter[1]	Whole Brain	Gray Matter[1]	PN	Whole Brain	Gray Matter[1]	White Matter[1]	Whole Brain	Gray Matter[1]	White Matter[1]	Whole Brain	Spinal Cord	Whole Brain	Gray Matter[1]
1 Water, %	70-85	65-75	80-85	60-75	80			70-85			75	80	65-75	75-80	68	80	80
2 Ash, %	1.5	1.4	0.92	0.7-1.8	1.0			1.15 PN	1.5	2.4		1.5	2.7	1.5-1.8	1.7	1.4	
3 Calcium	7-15	18	10.4	14	4-17			12-18	13	16	2-26			8.6-12	5.2-16	4.7-55*	45*PN
4 Chlorine	110-160	150	115-215	130-160	140		215	110-185	125	175	125-130	155	125	130-165	145	160-220	120
5 Copper	0.04-0.53		2.4-9.9#[2]	1.8-8.2#[2]				0.18PN									
6 Iron	5.2-8.3		30	21				4.4-8.2	5	7.4						4-9	
7 Magnesium	19-40	40	20	25				65*			13.0-13.5					14	75* PN
8 Manganese			0.16	0.2				1.3-10 PN						35			
9 Nitrogen, total, %	1.6-1.8[3]	1.6	1.6-1.7	1.7-1.8	1.7		2.5	2.1 PN	1.7	1.7	1.9	1.5-1.7	1.4-1.8	1.7		2.1	1.8
10 Acid-soluble, %			0.26[2]	0.33			0.14					0.14	0.13			0.13-0.18	
11 Amino					53		0.1					0.1	0.08			0.04	
12 Phosphorus, total	215-415	550	205-245	365-440	300		380-435	245-440	255	435	730[4]	250-260	440-470	330 PN		195-305	1090* PN
13 Inorganic	32-50[2]		40	45-64	14-46		25	16 PN			7-9[5]	55	50			13-20	16 PN
14 Acid-soluble	115-165[2]		140	240	67		51				65[5]	80	65-75			55-75	
15 Potassium	285-400	360	230-345	230-380	345			215-345			360-375	375	340	360-400	375-400	235-450	400
16 Sodium	110-300	200	120-205	160-225	120			75-165			115	150	120	120-145	145	110	115
17 Sulfur	207	85	55-75	90-150													
18 Zinc	0.7							0.22 PN								1.5	
19 Protein, total, %	10-11	9	7.3-8.2	7.7-9.2	9-11	10	10.9-12.3	10.3	10	8	12	8	8-13	8-9		11	
20 Neurokeratin, %		0.6 PN	0.31	1.12				0.48									
21 Lipid, total, %	13.3	2.3-18.5 PN	5.1-5.3	16.3-17.8	6		18-20	12			11-13			10.2-12.4		23-45	
22 Phospholipid, total, %	25*	22-30*	3.1-4.3	6.2-11.3	4.3-5.7	4.0-4.5	5.9-7.3	24-30*			4-5	3.9-4.2	8.3-8.5	5.0-5.6	10.6	4.7-5.8[6]	4.5
23 Cephalin, %	14.8-26.0*	0.4-1.2 PN	1.8-2.2	2.3-3.7	2.1-2.7	1.9	1.7-3.0	13-16*					2.8	2.8	5.4	5.2-8.4	
24 Lecithin, %	4.6-4.9*	0.3-0.6 PN	0.6-1.2	0.9-1.7	1.2-1.3	1.3	1.5[4]	6.6-7.5*						1.4	1.8	0.9-1.8	
25 Sphingomyelin, %	4.5-6.8*	2.6-2.8*	0.3-0.6	1.8-2.6	0.9	0.7	3.1[4]	5*			4			0.9	3.7	0.7-1.6	
26 Sulfolipid, %				0.4-0.8													
27 Cerebroside, %	1.2-2.4	5-6*	0.6-1.2	4.1-4.8	1.9-2.5	1.1-1.9	1.5-2.9	11.6-12.5*	1.2	5.3	3 PN	1.5	6.9-7.4	2.4-2.9	5.9	1.1-2	1.2
28 Cholesterol, %	2.6-4.4	0.53	0.8-1.1	3.8-4.2	2.2-2.8	1.2-1.3	3.2-3.4	10-11*						2.2	5.9	0.2-0.6	0.9
29 Nucleic acid, DNA	80	3.1-5.3[2,7]		4-9.8[7]	5.8[7]		4.3-5.8[7]				80	5[7]	6[7]	95		140	
30 RNA	105-140			12-26[7]	17.6[7]		3.6-3.9[7]				95	10[7]	5[7]	215		160	

/1/ Unspecified. /2/ Cortex. /3/ Infant. /4/ Spinal cord. /5/ % of total P. /6/ Plasmalogens 320-340 mg/100 g fresh tissue. /7/ As phosphorus.

Section 2: Other Animals

Values are mg/100 g fresh WHOLE BRAIN tissue unless otherwise indicated. * = dry weight; AX = axoplasm; GM = grey matter (unspecified); PN = peripheral nerve; SC = spinal cord.

Component	Beaver PN	Guinea Pig	Horse PN	Monkey	Mouse	Sheep	Chicken	Duck	Gull	Pigeon	Tortoise	Frog	Carp	Perch, Yellow	Shark, Sand	Invertebrates Value	Invertebrates Organism
1 Water, %		78	71	78	79	84GM	79	78	81	79	83	84[1]	81	82	81		
2 Ash, %			1.0			1.4GM						1.6	2.2				
3 Calcium		4-11				10.8						14 PN				5	Crab
4 Chlorine			230									130 PN		150		355AX	Squid
5 Nitrogen, total, %					2.2		1.1-1.2	1.7			1.2	1.5	1.3				
6 Phosphorus, total		300	250	390 PN	320							330 PN				78AX	Squid
7 Potassium			130-180		370							185 PN				420 PN	Cockroach
8 Sodium			450		100							145 PN				140 PN	Cockroach
9 Sulfur			40		260												
10 Protein, total, %		8.7-9.2		9.5SC	10.4	7.2-7.6	10.7			45-50*	8	6.7-7.5 PN	8			90-95*	Bee
11 Lipid, total, %		9.8-10.5				10.7	9.2-10.2	9.4		4.2-5.4	7.2		9.2			35-45*	Bee
12 Phospholipid	5.9	4.2-4.9	2.8	8.2 PN	4.5		4.2	3.7	4	4.4	4	3[1]	4	4.2	3.7	16-18*	Bee
13 Cephalin, %		2.8							2.3	2.4	2.2[2]	1.2[1]		1.7	2.8	10.1[3] AX	Squid
14 Lecithin, %		1.4							1.3	1.3	1.3[2]	1.3[1]		1.5	1.3		
15 Sphingomyelin, %		0.9							0.4	0.7	0.4[2]	0.7[1]		0.9	0.6	1-2*	Bee
16 Cerebroside, %	1.3	2.2-2.4							1.4	1.3	1.2[2]	1.2[1]	0.7	0.3	1.2		
17 Cholesterol, %	3.2	1.7 1.9				1.0	1.6-2	1.8	1.3	1.4-2	1	0.8[1]	1.1	1.3	1.1	0.8-1.6*	Bee
18 Nucleic acid, DNA		110					80	95			120		205				
19 RNA		255					165	160			385		265			160	

/1/ Leopard frog. /2/ Turtle. /3/ Cephalin + lecithin. %.

Part II: LUNG

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

	Component	Man	Cattle	Dog	Rabbit	Rat		Component	Man	Cattle	Dog	Rabbit	Rat
1	Water, %	78-80	80	78	80-82	77-85	12	Potassium	150		155-250		
2	Ash, %	1.1			1		13	Silicon[1]	20-40				
3	Bromine	0.3-0.7	0.35				14	Sodium	240		155-210	165	
4	Calcium	17					15	Zinc	4-15*				1.9
5	Chlorine	260		195-255	230	215-430	16	Protein, %	14.9-16.7				
6	Chromium, µg/100 g	13					17	Phospholipid, %	3.4	11.5*FF	14.2*FF	1.3[2]	6.6
7	Copper	0.5-1.4*					18	Cephalin, %	1.4-2.6*	3.7*			0.8
8	Iron	2-22			12.4		19	Lecithin, %	3.8-4*	3.3*			1.8
9	Magnesium	7	62*				20	Sphingomyelin, %	0.9-1.5*	2.3*			0.45
10	Phosphorus, total	95-120					21	Cholesterol, %	2.2*	2.2*FF			0.4
11	Nucleic acid	250*		265*		375*	22	Carbohydrate, %	0.4*				

/1/ As total silica. /2/ Total lipid.

Part III. HEART

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

	Component	Man				Cat	Cattle	Dog	Guinea Pig	Rabbit	Rat	Swine	Chicken
		Whole Heart	Left Ventricle	Right Ventricle	Auricles	Whole Heart							
1	Water, %	71-80	76-85	78-83	80-84	79-81	70-77	76-81	76	76-80	76-83	80	70
2	Ash, %	1.1	3.5-5.6*				0.92			1.0			
3	Aluminum	0.1-0.3						0.17			0.16	0.6	
4	Bromine	0.07-0.3						0.18		0.07			
5	Calcium		4.9-10.4	4.4-15.1			10	9.3	6.8	67*	3-20		
6	Chlorine	125-185	105-170	125-185	120-170	120-145	100[1]	110-135		125-180	85-110		
7	Chromium	0.01											
8	Copper	0.34	0.2-0.5			1.4*	0.76		2.1*	2.2*	0.2	1.5	1.5*
9	Fluorine	0.46											
10	Iron	35*	4-21				4.2-6.2	0.27[2]		12.4	5-11		
11	Lead	0.05-0.08											
12	Magnesium	17.4	13-25	13-30			110-125	21-23[2]	9	51*	18-26		
13	Manganese	0.02-0.05					0.03	0.21	0.02	0.02	0.06	0.2	0.07*
14	Phosphorus		145-235	125-185		207	160-235	217		175-240	240		
15	Potassium	275	245-355	190-240	95-220	300-365	255-355[2]	285-340	280	275	320-340	320	
16	Silicon	35-120*											
17	Sodium		85-140	80-165	75-170	95-110	80-135[2]	88	135	120-135	85-95	95	
18	Zinc	7-14						2		1.1-6.1			
19	Protein, %	16				17.6	16.5	18[2]					
20	Collagen, %		0.6-1.4	1.2-2.0	3.4-4.0	1.2	1.9[2]	2.7[2]	0.7-1.2	2*2	0.8	2.2*2	
21	Elastin, %					0.15	0				0.14		
22	Lipid, %	8.3	0.2-0.9	0.5-2.4			3.1-19.5			4[3]	0.4-2.4		
23	Phospholipid, %	6.3-7.5*FF					7.4-11.8*	11.7*			5-8*		1.5[2]
24	Choline-, %	6*FF					4.9*	5.3*			2*		
25	Cephalin, %	1.4-2.8*					5.3*				0.84		
26	Lecithin, %	3.3-5.7*					4*				2		
27	Sphingomyelin, %	0.2-0.5*					0.5*				0.14		
28	Cerebroside, %						2*				1.4*		
29	Cholesterol, total, %					0.44*2	0.4*4	0.6*	0.2	0.6*	0.4-0.6*		0.27
30	Glycogen					475		440-495	240	335-640	240-680		
31	Creatine	115-265	140-265	100-195		220-335		210-325		210-245	160-260		180*

/1/ Auricle. /2/ Ventricle. /3/ Total fat. /4/ Free cholesterol.

Part IV: MUSCLE

Section 1: Man, Cat, Cattle, Dog, Rabbit, Rat

Values are mg/100 g fresh muscle (type unspecified), unless otherwise indicated, * = dry weight; FF = fat-free.

Component	Man	Cat	Cattle	Dog	Rabbit	Rat
1 Water, %	74-84[1]	77	70	73-76	68-80	76
2 Ash, %	1.1		0.8-1		1.0-1.4	1.3
3 Bicarbonate	98[1]		70[1]			
4 Bromine	0.3-0.6					
5 Calcium	6.5-7.4	3.5	11	3.3	18	6.3[1]
6 Chlorine	45-110	55	55	50-75	50-100	40-140
7 Chromium, μg/100 g	0.2					
8 Copper	0.64-1.3*					
9 Iron	25.3		2.8-3.7		2.7	1.9
10 Magnesium	18.4-21.5	28.2[1]	32	44[1]	29	27[1]
11 Manganese, μg/100 g	8.2-10					
12 Nitrogen, %	3			3.5[2]		1.24[2]
13 Phosphorus, total	150-200	205	210	185-205[1]	245	185-250
14 Acid-soluble	175	165[1]		115-140[1]	150-185[1]	160-185
15 as PO_4	85-195[1]			75-120[1]	22-35[1]	75-105[1]
16 Potassium	300-435	350	260-525	320[1]	415	385-475
17 Sodium	65-105	55	45-165	74	40-55	40-60

Component	Man	Cat	Cattle	Dog	Rabbit	Rat
18 Zinc	12-30*					
19 Protein, %	18.5	18.2	19.3	21[1]	19-25	21[1]
20 Collagen, %			2.1*[FF]			0.65-2.0[4]
21 Elastin, %						0.07-0.37[4]
22 ATP[5]				40-60[1]	270-420[1]	330[1]
23 Anserine		90[1]		105[1]	370[1]	505[1]
24 Carnosine		250[1]		29[1]	100[1]	461[1]
25 Citric acid				1.1[6]	2.5	
26 Lactate	80-120[1]	15-20[1]		30-60[1]	39[1]	9-29[1]
27 Lipid, total, %	7.6	2.5	10-14	14	1.2-7.6	3.7-10.6
28 Fat, neutral, %			6-12*		7	0.75-1.8
29 Phospholipid, %			3.7*	5.8*		4.4-8.6*
30 Choline phospholipid, %			2.3*	2.9*		2.1*
31 Cholesterol, %	0.2*	0.2*	0.24*	0.3*	0.05	0.07
32 Hexose monophosphate		35-45[1]		35-55[1]	140-185	260[1]
33 Glycogen	1.3-2.2[1]	0.3-1		0.5-1.9[1]	140	270-320
34 Creatine	440[1]	380-440		370	380-440	440

/1/ Skeletal muscle. /2/ Sacrospinalis muscle. /3/ Collagen. /4/ Thigh muscle. /5/ Adenosine triphosphate. /6/ Abdominal muscle.

Section 2: Other Animals

Values are mg/100 g fresh muscle (type unspecified), unless otherwise indicated, * = dry weight; FF = fat-free.

Component	Guinea Pig	Sheep	Swine	Chicken	Pigeon	Snake[1]	Turtle	Frog	Cod	Eel	Salmon	Invertebrates Value	Invertebrates Organism
1 Water, %	75	52-64	65			74[1]	75-78	79	79-82[1]	72-83	54-59	64-70	78-84	Lobster
2 Ash, %		0.85	1				1				1.2[2]	1.2[3]	1.6	Lobster
3 Calcium		10-20				15-30			8-21[1]	25	9-16	17	107	Crayfish
4 Chlorine		70				35-125			40-65[1]	215	50-110	190		
5 Magnesium		33		100*[4]	110*[4]	4.6-10.2			24-65[1]	22	14.4	32	21	Crayfish
6 Phosphorus		185-210			260[1,5]	175-215			105-185[1]	220-240	190-200	230	140-180	Cockle
7 Potassium		205-295				85-140			305-350[1]	350	190-245	340	400	Crayfish
8 Sodium		80-140				110-145			55[1]	140	50-95	120	105	Crayfish
9 Protein, %	19-21[6]	17.1	19				14.5			25	13.5-15.3	25	14.2-20.1	Lobster
10 Lipid, total, %		17.5-32	8	7-12.7*[7]			17.4*	2-11	0.5*	26-30	18.3*	8.1*	Shrimp
11 Phospholipid, %		4.7	3.1*	2.7-4.4*[7]	3-5*[8]		5.3*	7.1*	4.3*		4.4*	4*	Shrimp
12 Cholesterol, %	0.1	0.26*	0.06	0.7*	0.11		0.7	0.04	0.05		0.06	0.710	Shrimp
13 Glycogen	290-910[6]				670					4-95[2]	24-65[3]	2600-4200	Oyster
14 Creatine	280-440			65[11]	36[11]	180-445		80[1]					

/1/ Skeletal muscle. /2/ Flatfish. /3/ Shark. /4/ Gluteus muscle. /5/ Aa phosphate. /6/ Gastrocnemius muscle. /7/ "Dark and white" meat. /8/ Pectoralis major muscle. /9/ Thigh muscle. /10/ Free cholesterol. /11/ Breast muscle.

Part V: GONADS AND SEX ORGANS

Values are per cent fresh tissue, unless otherwise indicated, * = dry weight; FF = fat-free.

Component	Man			Cattle	Dog	Guinea Pig	Rabbit	Rat				Swine
	Ovary	Uterus	Testis	Prostate	Testis	Testis	Mammary	Mammary	Ovary	Uterus	Testis	Prostate	Prostate
1 Water	80.5 FF		84	82.5	86	83-92 FF	80	38[1]	73-75	82-89 FF	87.3 FF		15.6
2 Solids, total				16-20	21.8[2]		10.3*	12.5 FF	23.5-25			18-26[3]	
3 Ash				0.83				0.3	1.1-1.6	0.9-1.1	1-1.6	0.85-1.2[3]	
4 Bromine, mg/100 g		0.3-0.8	0.26	0.28	0.27								
5 Chlorine, mg/100 g[4]		210				205-225 FF		135[5]		140-150	330		
6 Potassium, mg/100 g[4]		290				315-390 FF				240-260			
7 Uranium, μg/100 g	3.3			4.0		1.7		1.4-16.7[6]					
8 Zinc, mg/100 g			6.8-16.3*	9.4-25	4.12			17-36[2]	1.9-2.3	1.1-1.8	2.7-3.1	13-25[7]	3.8
9 Lipid, total				1.2	1.6		9.7	12.3[8]			1.1		
10 Fatty acids				0.12			76.1*[9]	89.3[9,10]			0.8[12]		
11 Cholesterol, total				0.22-0.8			0.26[6]		1.2[11]				
12 Citric acid					14.3-23.2[13]		80-100	52-62[2]				70-120[3]	38

/1/ In lactation, 55-75% H_2O. /2/ Prostate. /3/ Ventral. /4/ Of tissue water. /5/ Ovary. /6/ Testis. /7/ Posterior. /8/ Early lactation. /9/ Calcium salts. /10/ Per 100 g dry fat. /11/ Immature ovary. /12/ Free cholesterol. /13/ Mammary.

Part VI: TEETH

Section 1: Man

Values are per cent dry tissue, unless otherwise indicated. FW = fresh tissue; TA = tissue ashed.

	Component	Whole Teeth	Enamel	Dentine	Pulp
1	Water	4-14.3 FW	0.5-6.6 FW[1]	4.2-16.7 FW[1]	
2	Ash	68-80	95.4	71.1	21.2
3	Calcium	27-37 TA	35-39	27.8	5.7
4	Chlorine		0.3	0	
5	Copper, mg/100 g	0.52 TA			
6	Fluorine, mg/100 g	4.5-28.7 FW	0-25	13.3-32 FW	
7	Lead, mg/100 g	5.1 TA			
8	Magnesium	0-1.8 FW	0.16-1.16 TA	0.8-1.6 TA	
9	Nitrogen				10.1
10	Phosphorus	16.5-19.0 TA	16.8-18.5 TA	16.5-19.0 TA	3.5
11	Potassium		0.05[2]	0.07	
12	Silicon, mg/100 g	3.0			
13	Sodium		0.25	0.2	
14	Zinc, mg/100 g	0.3 TA	15.2-25 TA	14.8-26 TA	
15	Carbonate[3]	3-5 TA	2.6-3.7 TA	4.3-5.1 TA	
16	Protein, total	18 FW			60-65 FW
17	Insoluble		0.2-0.5 FW	15.5 FW	
18	Fat, total				0.9 FW
19	Phospholipid				0.7 FW
20	Cholesterol, mg/100 g				0.11 FW
21	Citric acid	0.7	0.09	0.8	

/1/ Deciduous. /2/ Or less. /3/ As CO_2.

Section 2: Other Mammals

Values are per cent dry tissue, unless otherwise indicated. FW = fresh tissue; FF = fat-free tissue; TA = tissue ashed.

	Component	Dog	Elephant	Guinea Pig	Hamster		Hare	Horse	Monkey	Rabbit	Rat		Swine
		Dentine	Dentine[1]	Whole Teeth[2]	Enamel[2]	Dentine[2]	Whole Teeth[2]	Dentine	Dentine	Whole Teeth[2]	Enamel[2]	Dentine[2]	Pulp
1	Ash				85-92	74-76							3.8 FW
2	Calcium	37.6 TA	32.9 TA	35-36 TA	25-34	19-24	36 TA	37.1 TA	37 TA	35-36 TA	33-35 FF	27-28 FF	0.23 FF
3	Fluorine, mg/100 g	28-41 FW[3]											4.2 FW
4	Magnesium		4.1 TA	1.7 1.9 TA	0.7-1.3	0.8-1.5	1.8-2.3 TA	1.9 TA			1.5-2.5 TA	0.25-0.44 FF	0.37-1.5 FF
5	Phosphorus	19.6 TA	19.6 TA	20 TA	17-18	14-16	19-20	19.2 TA	20 TA	20 TA			0.07 FW
												15.9-17.4 FF	0.23 FW

/1/ Tusk. /2/ Incisors and molars. /3/ Whole teeth.

Part VII: BONE

Section 1: Man, Cattle, Dog, Horse, Rabbit, Rat

Values are per cent fresh tissue (compact bone) unless otherwise indicated. * = dry weight; FF = fat-free tissue; Unspec. = bone type not specified.

	Component	Man				Cattle		Dog		Horse		Rabbit		Rat	
		Bone Type													
		Unspec.	Epiphysis	Femur	Rib	Bone Type	Value	Bone Type	Value	Bone Type	Value*	Bone Type	Value	Bone Type	Value
1	Water	30-44	84[1]		81			Unspec.	40-59			Unspec.	39-58	Femur	34.6
2	Ash	22.1		66.8*FF		Femur	75*FF	Unspec.	25-30	Femur	70.2	Femur	72*FF	Unspec.	34-60
3	Calcium			25.6*FF	25.6*FF	Unspec.	25.8*	Femur	25.5*FF	Femur	26.2	Femur & tibia	27-31*FF	Femur & tibia	27-29*FF
4	Carbonate, as CO_3			4.0*FF		Unspec.	5.8*FF	Femur	4.5*FF	Femur	5.7			Femur	5.2*FF
5	Chlorine	0.17								Femur	0.192	Unspec.	0.182	Unspec.	
6	Copper, mg/100 g	0.65*		0.2	0.37-4.8										
7	Fluorine, mg/100 g				61-310*FF	Rib	36-51*FF			Femur	100	Long bone	12-18*FF	Femur & tibia	10-29*FF
8	Iron, insorg., mg/100 g	10.3-16.1[3]			11.2-16.7							Unspec.[4]	8.1		
9	Magnesium		0.015	0.39*FF	0.02	Femur[5]	0.42-0.64*FF	Femur	0.44*FF	Femur	0.23			Femur	0.54*
10	Manganese, mg/100 g	0.3			0.2	Femur	0.05					Femur	0.7*	Unspec.	2.2
11	Nitrogen			4.2-4.6*FF	5.1*FF	Rib	4.25*	Femur	5.27*FF	Femur	5.4	Femur & tibia	2.9-3.5*FF	Femur & tibia	3.0-3.7*FF
12	Phosphorus	11.5*FF		12.3*FF		Unspec.	11.9*	Femur	11.9*FF	Femur	11.4	Unspec.	3.6-4.2	Femur & tibia	11.9-13.5*FF
13	Potassium	0.055	0.2		0.3					Femur	0.02				
14	Sodium	0.44*FF						Unspec.	0.44*FF	Femur	0.39				
15	Strontium	0.06-0.22[6]													
16	Fat					Femur	0.1*	Unspec.[7]	13.0			Femur	0.1*	Unspec.[7]	5-7
17	Citric acid	0.7-2.0*FF		1.4-1.9*FF	1.4-2.1*FF	Leg bones	0.27	Femur	1.5-1.3*FF			Tibia	0.72-0.83*	Tibia	0.3-0.42*

/1/ Cartilage. /2/ mg/100 g. /3/ Vertebrae. /4/ Compact and spongy (cancellous) bone. /5/ Femur head spongy bone. /6/ Tibia. /7/ Total lipid.

Section 2: Other Vertebrates

Values are per cent dry, fat-free tissue (compact bone), unless otherwise indicated. FW = fresh tissue.

	Component	Cat		Ferret		Guinea Pig		Sheep		Turkey		Turtle		Frog	
		Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value
1	Ash	Femur	67-70					Rib[1]	61-64	Femur	69.5	Femur	62.7	Femur	67.6
2	Calcium	Femur & tibia	26-29	Femur & tibia	26-31	Femur & tibia	28-31	Rib[1]	22.2-23.0	Femur	26.5	Femur	24.3	Femur	26.2
3	Carbonate, as CO_3					Femur & tibia	5.0[2]	Femur	4.7	Femur	4.5	Femur	5.6[2]	Femur	4.7[2]
4	Magnesium							Femur	0.52-0.70	Femur	0.52	Femur	0.54		
5	Nitrogen	Femur & tibia	3.4-4.6	Femur & tibia	3.3-4.5	Femur & tibia	2.7-3.1	Femur & tibia	2.9-3.5	Femur	4.9	Femur	5.9	Femur	5.2
6	Phosphorus	Femur & tibia	11.5-12.9	Femur & tibia	11.5-13.2			Rib	10.8	Femur	12.6	Femur	10.5	Femur	12.3
7	Citric acid	Rib	0.4-0.6 FW											Unspec.	0.29

/1/ Compact and spongy bone. /2/ Per cent of ash, calculated as CO_2.

Part VIII: BONE MARROW

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component	Man			Cat	Cattle	Dog	Guinea Pig	Rabbit			Rat	Swine	Frog
	Sternum	Tibia	Unspec.[1]	Femur	Femur	Femur	Femur	Femur	Rib	Combined[2]	Femur	Femur	Femur
1 Water, %	14.0			50	41.3	21.0	71	74	46-55	7-16	68	8.1	65
2 Ash, %	0.55												
3 Calcium	32.7	4.4-11.0											
4 Copper					0.35[3]			0.07-0.09[3]		0.2-0.4[1]		2.2[4]	
5 Iron	30-55												
6 Phosphorus	18.3							7.6		2.4-3.6			
7 Protein, %				11.5	1.4	5.4	17.0				17.2	1.2	5.4
8 Fat, %			30-90	38.2			10.4	56			14.0		28.4
9 Sugar	65-275	11-55											

/1/ Unspecified origin of marrow. /2/ Radius + ulna + distal end of tibia. /3/ "Leg (long) bones." /4/ Rib.

Part IX: LIVER

Section 1: Man, Cattle, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component	Man	Cattle	Rabbit	Rat
1 Water, %	73-77	69-71	70-76	69-72
2 Ash, %	1.4	1.4	1.2-2.0	1.4-1.6
3 Arsenic	0.15			
4 Bromine	0.04-0.43	0.7		
5 Calcium	7.2-9.4	8.3	5-16	2.8-3.8
6 Chlorine	96-150		105-160	90-115
7 Chromium, μg/100 g	0.6			
8 Copper	1.5-13	8.5	3.0[1]	2.1-20.4*
9 Iron, total	13.4	12.1	18.5	3.0-22
10 Inorganic	3.0-16.2		8.2-10.3	7.0-18.2
11 Lead	0.2			
12 Magnesium	17	60-75*	13.4	19
13 Manganese	0.08		0.2	
14 Phosphorus, total	180-240	375		280-375
15 DNA[2]	19	34		20-37
16 RNA[3]	37	70		55-120

Component	Man	Cattle	Rat
17 Potassium	170-250	225-395	190-260
18 Silicon	5-20		
19 Sodium	120-150	53-345	75-140
20 Zinc	5.4	3.4-8.4	22
21 Protein, %	17.0	20.0	
22 Collagen, %	0.5-1.5		
23 Elastin, %	0.1-0.5		
24 Lipid, total, %		6-7.4	
25 Fat, total, %		7.0	0.23
26 Phospholipid, %	9-11*	17.1-25.1*	
27 Cephalin, %	3.0-5.4*	5.0*	
28 Lecithin, %	3.3-6.0*	8.0*	
29 Sphingomyelin, %	0.3-0.43*	0.8*	
30 Cholesterol, total, %	0.2-0.4	0.32	0.05
31 Carbohydrate, %		4.0	
32 Ascorbic acid	5.0		

/1/ In the newborn. /2/ Desoxyribonucleic acid P. /3/ Ribonucleic acid P.

Section 2. Other Vertebrates

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Cat	Dog	Guinea Pig	Mouse
1 Water, %	70-72	73-75	70-75	
2 Calcium		5.0-22	4.2	
3 Chlorine	94-103	149		
4 Copper	2.0[1]		5.1[1]	5.0
5 Iron, total				
6 Inorganic	23.2[1]		4-5	1.1-3.1
7 Magnesium				350-385*
8 Phosphorus	280	80-140[2]	110-175[2]	
9 Potassium	290	115-275		
10 Sodium	76	120		
11 Zinc	15[1]		4.3	20
12 Protein, %	17.1			
13 Fat, total, %	6.0	4.0[3]	2.0-3.2	6.4
14 Phospholipid, %		12.0	2.0-3.0	3.2-4.2
15 Cholesterol, total, %			0.17-0.54	0.4-0.7

Component	Sheep	Swine	Chicken	Eel
1 Water, %	67	78		80
2 Calcium				9.0
3 Chlorine				195
4 Copper	10-135	1.3-3.5*	0.4*[4]	
5 Iron, total	9-45	6.4*	6-35	105
6 Inorganic		2.6*		28-83
7 Magnesium	73*			11.4
8 Phosphorus				245
9 Potassium				195
10 Sodium				205
11 Zinc		3.0		
12 Protein, %				13.2
13 Fat, total, %				6.5
14 Phospholipid, %			2.0-3.4	
15 Cholesterol, total, %	0.14	0.13*FF	0.3-0.6	

/1/ In the newborn. /2/ Nucleic acid P. /3/ Total lipid. /4/ In the young animal.

Part X: SPLEEN

Section 1: Man, Cattle, Rabbit, Rat.

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man	Cattle	Rabbit	Rat
1 Water, %	76-81		78-79	77-78
2 Ash, %	1.5		1.0	
3 Bromine	0.23-0.6	0.5		
4 Calcium	9.3			
5 Chlorine	160		150	140-160
6 Chromium, µg/100 g	1.6			
7 Copper	0.12-1.3	0.65*	2.4[1]	
8 Iron, total	28			35-40
9 Inorganic	8.5-17			3.5
10 Magnesium	14.2	70-85*		
11 Phosphorus, total	375	90-205[2]		165-260[2]
12 DNA[3]	75	95	80-95	55-145

Component	Man	Cattle	Rabbit	Rat
13 Phosphorus, RNA[4]	35	50	65-80	35-85
14 Silicon	5-20			
15 Zinc	6-9*		9.3-9.9[1]	
16 Protein, %	17.5			
17 Collagen, %	0.6-1.5	3.1*FF		3.5*FF
18 Elastin, %	0.13-0.5	4.6*FF		0.6*FF
19 Lipid, total, %	3		0.44	0.8-1.3
20 Phospholipid, %	5.5-11.3*			10.8*
21 Cephalin, %	1.6-6.9*			1.2
22 Lecithin, %	3-4*			1.1
23 Sphingomyelin, %	0.7-1			0.2
24 Cholesterol, %				0.3

/1/ In the newborn. /2/ Nucleic acid P. /3/ Desoxyribonucleic acid P. /4/ Ribonucleic acid P.

Section 2: Other Mammals

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Cat	Guinea Pig	Mouse	Swine
1 Water, %			81	
2 Copper	2[1]	5.1	4-7[1]	5.4[1]
3 Iodine, µg/100 g				1.5
4 Iron, inorganic	23.2[1]	4.1[1]	16[1]	8.5[1]
5 Phosphorus, DNA[2]	75-95		130	

Component	Cat	Guinea Pig	Mouse	Swine
6 Phosphorus, RNA[3]	85-150		80	
7 Zinc	15[1]	4.3[1]	19.9[1]	3[1]
8 Collagen, %		0.5-1.5		2.4*FF
9 Elastin, %				1.3*FF
10 Cholesterol, %		0.43	0.8	

/1/ In the newborn. /2/ Desoxyribonucleic acid P. /3/ Ribonucleic acid P.

Part XI: KIDNEY

Section 1: Man, Cattle, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component	Man	Cattle	Rabbit	Rat
1 Water, %	78-79	75	74-80	75-77
2 Ash, %	0.8	1.1	1.3	1.3-1.5
3 Calcium	19.2	14	5	6-11
4 Chlorine	190-210		225	200-320
5 Chromium, µg/100 g	8.5			
6 Copper	0.2-0.4	1.1	0.014*	0.018*
7 Iodine, µg/100 g		2.3	5	
8 Iron	41	11-15	9	
9 Lead	0.14			
10 Magnesium	21	80-85*	13.4	18-25
11 Manganese, µg/100 g	21-30			
12 Phosphorus	170	260		290[1]
13 Potassium	170	225-240	340	300-330

Component	Man	Cattle	Rabbit	Rat
14 Silicon	5-20			
15 Sodium	165	145-170	150-250	
16 Uranium, µg/100 g	0.3-1.3			
17 Zinc	5.4			14.4-50*
18 Protein, %	18	15		18
19 Lipid, total, %	5.3	4.4	1.1	1.1-3
20 Phospholipid, %	7.3-9.1*	7.7-9.1*		2.4
21 Fatty acids, %	2			
22 Cephalin, %	2.3-4.3*	2.1*		0.95
23 Lecithin, %	4.4-6.6*	5.5*		1.4
24 Sphingomyelin, %	0.6-0.8*	1.6*		0.3
25 Cholesterol, %	0.3-0.4	0.41		0.3
26 Citric acid			6	4-8

/1/ Nucleic acid P.

Section 2: Other Mammals

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Dog	Guinea Pig	Sheep	Swine
1 Water, %	79	77-84	77-80	
2 Chlorine	230			
3 Copper, µg/100 g	14.2*	19.9*	17.8*	2700*
4 Iodine, µg/100 g			1.4	1.5
5 Magnesium			95*	

Component	Dog	Guinea Pig	Sheep	Swine
6 Phosphorus	50*		1100-1400*	
7 Potassium	230 FF	220-265		
8 Lipid, total, %	2			
9 Cholesterol		0.5	0.2-0.4	0.4
10 Citric acid	1.6	3.9		

/1/ Nucleic acid P.

Part XII: EYE

Section 1: Man, Cat, Dog, Horse, Rabbit, Whale, Frog, Perch, Trout

Values are mg/100 g fresh tissue, unless otherwise indicated, * = dry weight; TA = on basis of total ash.

Component	Man		Cat	Dog	Horse		Rabbit		Whale	Frog	Perch	Trout
	Lens	Aqueous Humor	Lens	Aqueous Humor	Aqueous Humor	Vitreous Humor[1]	Lens	Aqueous Humor	Lens	Lens	Lens	Lens
1 Water, %	68		74		99.7	99.7[2]	69-71					
2 Calcium, %	0.45 TA				6.2	6.8						
3 Chlorine	2.1 TA	410-435[3]		460[3]	430-460	415		295-410				
4 Copper							0.05		0.42*	3.0*	0.09*	0.24
5 Magnesium					2.6	2.2						
6 Nitrogen, total				25-55	27	30						
7 Non-protein				12-40	24	26		11-23				
8 Phosphorus, total	3.4 TA		77	23[4]	35[5]	22-30[5]	42-44					
9 As phosphate	0.54[4]			0.8-1.5[6]	3.3	3.1		5-8[3]				
10 Potassium	15 TA	13.0-24.5[7]			19	19.2	450-480[3]	56				
11 Sodium	8 TA	400-415[3]		365[3]	540-675[8]	280	275	50-70[3]	335[3]			
12 Sulfate	1.2*				0.2-0.5[9]	6.1	6.2					
13 Zinc							1.3-1.6		3.5*	7.8*	1.6*	0.7
14 Protein[10], total, %	3.2-6.5						21.5[11]	0.05-0.14				
15 Fat, total, %	0.9-2.3											
16 Glucose	25-60	55-110		57[3]	74	98	97	100-125	120-130[3]			
17 Urea				40-55		28	29	19-60	22-70			

/1/ Except for H_2O, values are mg/100 ml fluid. /2/ Lens has 66-69% H_2O. /3/ Mg/100 mg fluid. /4/ Young animal. /5/ Lens. /6/ As P_2O_5. /7/ Vitreous humor. /8/ As NaCl. /9/ As S. /10/ Amino acid composition is roughly the same as that for bovine total lens protein - see Section 2. /11/ Mucoprotein.

Section 2: Cattle.

Values are mg/100 g fresh tissue, unless otherwise indicated. Amino acids are mole % of total protein. * = dry weight.

Component	Choroid	Conjunctiva	Cornea	Aqueous Humor	Vitreous Humor	Iris	Lens	Retina	Sclera
1 Water, %	82-84	81-82	82-84	99	81-82	64	86	70-73	
2 Ash, %	1.1-1.4	0.4-1	0.6-0.9	0.85-0.94	0.8-0.9	0.8-1.2	0.68-0.73	0.9-1.0	0.4-0.5
3 Calcium							6		
4 Chlorine			280-285	360-515	410		60-69	145	225
5 Copper	0.3-0.4	0.13-0.21	0.14-0.23	0.01	0.02-0.34	0.18-0.41	0.12-0.24	0.12-0.4	0.14-0.25
6 Iron	1.3-3.0	0.24-0.3	0.21-0.3	0.02	0.012	0.3-0.4	0.03	0.4	0.4
7 Magnesium			3		2		8	11	2
8 Manganese, µg/100 g	17-30	7-11	9.4-12.5	1.0-1.5	2-4.2	21-30	14-22	24-40	8-13
9 Phosphorus							90-95		
10 Potassium			90-95	27	17-30		405	50	71
11 Sodium			265		300		45	155	185
12 Sulfate							470		
13 Zinc	0.22	0.16	0.2	0.03	0.03	0.4	0.18-0.33	0.3	0.18
14 Lipid, total[1], %							0.32		
15 Phospholipid, %							0.19	0.09	
16 Inositol	29-35[2]	6	6.5-8.0		+	22-35	125-175	13.4-17	10.5-14
17 Citric acid	2.4-4.3[2]	1.0	1.1-1.5		0.9-1.2	1.3-1.7	1.8-2.4	1.0-1.6	1.1-1.5
18 Formic acid	1.6-2.1		0.8-1.6		0.8-1.7	1.9-3.5	1.0-1.2	0.8-1.4	0.9-1.3
19 Lactic acid							55-65		
20 Malic acid	18.5-29	6.5	8.8-14.9		7.7-8.1	10.4-13.3	9.9-13.5	12.9-13.9	6.9-8.1
21 Hyaluronic acid				4.0	62				
22 Creatine	37-55		25-35		2.1-5.3	45-70	45-80	7.7-13.7	
23 Creatinine	2.1-2.5	1.1-1.9	1.1-2		0.85-1.1	1.1-1.3	0.86-1.2	1.3-1.5	0.85-1.1
24 Spermine	3.1-4.2	2.1-2.9	4.9-8.8		0	35-40	2.9-5.8	25-35	0.1-0.3
25 Carnosine	16.1-17.8	9.9-11.3	4.4-4.7		0.16-0.29	3.2-4.1	4.7-5.7	2.6-3.0	1.7-2.6

Component	Choroid	Conjunctiva	Iris	Lens
26 Protein, H_2O-sol,%	9.3-18.1	10.4-16.9	4.0-7.4	
27 H_2O-insol, %	8.5	14	11.2	
28 Albumin, %[4]				0.9-2.4[5]
29 Collagen, %	4.8	11.2	7.2	
30 Elastin, %	1.6	1.1	0.7	
31 Mucoprotein, %	2.1	1.6	3.3	
32 Pigment protein	3.3		4	
33 Alanine				4.7
34 Arginine	14.2*[6]		9.2*[6]	8.2
35 Aspartic acid				7.9
36 Cystine	4.2*[6]		2.2*[6]	1.8
37 Glutamic acid				11.0
38 Glycine				9.3
39 Histidine	1.6*[6]		1.3*[6]	3.5
40 Isoleucine				5.7
41 Leucine				7.4
42 Lysine	1.3*[6]		5.2*[6]	4.8
43 Methionine				2.0
44 Phenylalanine				6.5
45 Proline				2.6
46 Serine				9.2
47 Threonine				3.5
48 Tryptophan	0.75*[6]		0.73[6]	1.5
49 Tyrosine	4.8*[6]		4.7*	4.7
50 Valine				5.7

/1/ In the lens the following lipid components are also present (as mg/100 g tissue): fatty acids, 1.0; cephalin, 31; lecithin, 125; sphingomyelin, 38; cholesterol, 65; cerebroside, 4.2; unsaponifiable substances, 55. /2/ Choroid + pigmented epithelium. /3/ In lens, α-crystallin = 32 %, and β-crystallin = 53 % of total protein. /4/ Albumin + globulin: choroid, 2.4 %; iris, 1.0 %; sclera, 0.6 % of total protein. /5/ % of total protein. /6/ % of mucoprotein.

Part XIII: SKIN

Section 1: Man

Values are mg/100 g fresh, non-fat-free whole skin, unless otherwise indicated. * = dry weight.

Component	Value	Component	Value	Component	Value	Component	Value
1 Water, %	70-75[1]	14 Nitrogen, combined amino acid	20-51	27 Collagen, %	35-40[1]	40 Histamine	0.1-0.24
2 Ash, %	1.4-2.6*[1]	15 Free amino acid N	17-31	28 Lipid, total, %	0.3-10	41 Hyaluronic acid	19-30
3 Boron	1.7-17.2*	16 Creatine N	0.4-0.6	29 Fats and fatty acids, %	1.0	42 Urea	330[2]
4 Calcium	8.6-12.8[1]	17 Creatinine N	1.1-1.6	30 Cholesterol, total	370*[1]	43 Ascorbic acid	0.2-0.7*
5 Chlorine	265-300[1]	18 Urea N	6-11.5	31 Combined	160	44 Biotin, μg/100 g	2.3-8.5*
6 Copper	3-19*[1]	19 Uric acid N	1.0-1.3	32 Free	85	45 Choline	120
7 Iodine	0.13-0.2*	20 Ammonia N	17-46	33 7-Dehydrocholesterol	430[2]	46 Cobalamin, μg/100 g	1.6-2.4*
8 Iron	0.9-5.9*	21 Phosphorus	30-105*	34 Δ-7-Cholestanol	1500[2]	47 Folic acid, μg/100 g	0.9-15*
9 Lead	25-135*	22 Potassium	51-77[1]	35 Ergosterol, % total sterols	0.42	48 Inositol	23-79*
10 Magnesium	4.5-5.9[1]	23 Silicon, %	0.64-2.1*	36 Glucose	55-80	49 Pantothenate	0.13-0.71
11 Nitrogen, total, %	16.1*[1]	24 Sodium	205-260[1]	37 Glycogen	45-115	50 Pyridoxine	18-66*
12 Non-protein, %	3.0*[1]	25 Sulfur	290-340*	38 Sugar, non-fermentable	12	51 Nicotinic acid	0.9-2.4*
13 Collagen, %	11.3*[1]	26 Zinc	1.2-5.5[1]	39 Chondroitin H_2SO_4	20-30	52 Riboflavin	1.2-3.4*
						53 Thiamine	20-40*

/1/ Fat-free tissue. /2/ Epidermis.

Section 2: Other Vertebrates

Values are mg/100 g fresh, non-fat-free whole skin, unless otherwise indicated. * = dry weight.

Component	Dog*[1]	Guinea Pig*[1]	Mouse[2]	Rabbit	Rat[1]	Frog	Eel	Component	Dog*[1]	Guinea Pig*[1]	Mouse[2]	Rabbit	Rat[1]	Frog	Eel
1 Water, %	68-74		60	67-69[3]	205*		66-68	8 Potassium	275-390	215-245	345	100-190*	370-445*	130-145	150
2 Ash, %				0.72				9 Sodium	605-890	350-410	125	115-245*	210-245*	90	145
3 Calcium	31-58	32-100	44	50-85*	64-87	300	670	10 Protein, %	26-32[3]	34.4[4]			25-30[5]		25-26
4 Chlorine	960-1185	570-1815		250-265[1]	635-1440*	170	155	11 Collagen N, %	10.5-12[4]	23.4			25-30		
5 Iron			6.4				5.3	12 Lipid, total, %	25[3.4]		28.6	1.6	13-17[4]		
6 Magnesium	18-27	30-55	19	15-50*	20-28*[3]	4	19.4	13 Fat, total, %	16-48[3.4]			1	1.9-7.6		5-6
7 Phosphorus					345*[3]	340	405	14 Cholesterol				425-630*	305-465[4]		

/1/ Fat-free tissue. /2/ Epidermis. /3/ Fresh tissue. /4/ Non-fat-free.

Part XIV: KERATINOUS APPENDAGES OF THE SKIN

Section 1: Hair: Man

Values are mg/100 g fresh hair, unless otherwise indicated. Unspec. = type and color not specified.

Component	Unspec.	Brown	Black	Component	Unspec.	Brown	Black	Component	Unspec.	Brown	Black
1 Water, %	4.1	4.0	4.2	8 Chromium	0.2			15 Phosphorus	ơ80	245	295
2 Ash, %	0.23-0.73[1]	0.92	0.53	9 Cobalt	ơ1.8	ǫ1.4	ǫ1.6	16 Sulfur, %	ơ3.8	ǫ3.8	
3 Aluminum	ơ3.2	ǫ2.6	ǫ2.6	10 Copper	ơ10.8	ǫ6.3	ǫ6.4	17 Uranium, μg/100 g	ǫ12.7		
4 Arsenic	ơ0.22	0.24	0.22	11 Iron	ơ14.1	ǫ13.3	ǫ12.6	18 Zinc	ơ21.2	ǫ11.6	18.2
5 Bromine	0.2-0.7			12 Lead	ơ4.8	ǫ2.1	ǫ28.4	19 Sugars[3]	80		
6 Calcium	ơ20.8	ǫ21.2	ǫ18.8	13 Manganese	ơ3.8	ǫ2.8	ǫ2.5	20 Pentose	30		
7 Chlorine, %	ơ2.0	ǫ2.0	ǫ2.0	14 Nickel	ơ0.8	ǫ0.5	ǫ0.55	21 Protein	91	85	85

/1/ Dry weight, fat-free. /2/ Red hair. /3/ Reducing substances determined as glucose.

Section 2: Hair and Other Appendages: Vertebrates Other Than Man

Values are mg/100 g fresh weight hair or other tissue, unless otherwise indicated.

Component	Cat	Cattle	Chimpanzee	Dog	Guinea Pig[1]	Hedgehog	Horse	Mouse	Rabbit[2]	Rat	Sheep	Swine	Man	Cattle	Horse	Chicken
						Hair, Unspecified							Nail	Horn	Hoof	Feather
1 Water, %									10-13		9-28	11.4	0.07-0.72			9.1
2 Chromium													0.12			
3 Copper					0.1-4.7				0.9-4.1	1.4-3.2[3]						
4 Lead		0.6			0.04-0.64						1-3					
5 Sulfur, %		3.6-3.9[4]	4.2-4.4[4]				2.9				3.2-3.9		3.3-3.5		2.2	
6 Zinc				17.2		4.9					16.4		10.8[5]	12.9[5]		
7 Sugars[6]	250								230	130[3]	200					
8 Pentose									200	60[3]	50					
9 Protein, %		91-100[7]	104[7]				98								90	73
10 Cholesterol									450	640-830[8]						
11 Citric acid							27.7	95-135								

/1/ Black, brown, white. /2/ Various colors. /3/ White. /4/ Dry weight, ash-free. /5/ Dry weight. /6/ Reducing substances determined as glucose. /7/ Nitrogen x 6.25. /8/ Total sterols.

56. INSECT TISSUES: CHEMICAL COMPOSITION

	Constituent	Organism	Stage	Tissue		
				Type[1]	Condition	Value[2]
1	Allantoin	Silkworm, Chinese oak (Antheraea pernyi)	Larva	FB	Wet	82 mg %
2	Aluminum	Bee, honey (Apis mellifera)	Adult	W	Dry	0.01%
3	Amino acids	Mosquito spp	Adult	W		+
4		Silkworm (Bombyx mori)	Adult	W		+
5	Ammonia	Blowfly, Australian sheep (Phaenicia cuprina)	Larva	FB		21 mg %
6		Blowfly, Australian sheep (P. cuprina)	Larva	HHG		340 mg %
7		Silkworm, Chinese oak (Antheraea pernyi)	Larva	FB	Wet	13 mg %
8	Ascorbic acid	Beetle, diving (Dytiscus marginalis)	Adult	G	Wet	0.031%
9	Barium	Many insects from various families	Adult	W		+
10	Boron	Mealworm, yellow (Tenebrio molitor)	Larva	W		+
11	Chitin	Bee, honey (Apis mellifera), drone	Pupa	W	Dry	1-1.6%
12		Bee, honey (A. mellifera), worker	Pupa	W	Dry	4.8%
13		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W	Dry	5-9%
14		Silkworm (Bombyx mori)	Larva	W	Wet	0.04-0.08 %
15	Cholesterol	Mealworm, yellow (Tenebrio molitor)	Larva	W	Wet	0.1-0.6%
16		Moth, privet hawk- (Sphinx ligustri)	Pupa	W	Wet	0.09%
17		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	W	Wet	0.07%
18	Copper	Bee, honey (Apis mellifera)	Adult	W	Dry	0.006%
19		Beetle, confused flour- (Tribolium confusum)	Pupa	W	Wet	26 mg/kg
20		Cockroach, American (Periplaneta amer.)	Adult	W	Wet	31 mg/kg
21		Cockroach, oriental (Blatta orientalis)	Adult	W	Wet	14-24 mg/kg
22		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W	Wet	13 mg/kg
23		Grasshopper, differential (Melanoplus diff.)	Egg	W	Wet	28 mg/kg
24		Silkworm (Bombyx mori)	Larva	W		0.002%
25		Silkworm, cecropia (Samia cecropia)	Pupa	W	Wet	10 mg/kg
26	Fatty acids	Beetle, adult (Leptinotarsa decemlineata)	Adult	W	Wet	1.5-15%
27		Locust, migratory (Melanoplus mexicanus mex.)	Adult	W	Dry	2.4%
28		Mealworm, yellow (Tenebrio molitor)	Larva	W	Wet	6.6-14.3%
29		Scale, white wax (Ceroplastes destructor)	Adult	Wax	Dry	82%
30		Silkworm (Bombyx mori)	Larva	W	Wet	0.5-4.8%
31	Flavins	Beetle, diving (Dytiscus marginalis)	Adult	MT	Wet	100 mg %
32		Cricket, house (Acheta domesticus)	Adult	MT	Wet	8 mg %
33		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W	Wet	1.2 mg %
34		Locust, desert (Schistocerca gregaria)	Adult	W	Wet	2.3 mg %
35		Mealworm, yellow (Tenebrio molitor)	Adult	MT	Wet	16 mg %
36	Glycogen	Moth, goat (Cossus cossus)	Larva	W	Wet	2.3 mg %
37		Moth, privet hawk- (Sphinx ligustri)	Pupa	MT	Wet	150 mg %
38		Roach, oriental (Blatta orientalis)	Adult	MT	Wet	10 mg %
39		Silkworm, Chinese oak (Antheraea pernyi)	Adult	W	Wet	0.8 mg %
40	Iodine	Armyworm, southern (Prodenia eridania)	Adult	W	Dry	0.8-2.9 %
41		Bee, honey (Apis mellifera)	Larva	W	Dry	0-32.5%
42		Caterpillar, tent (Malacosoma armigera)	Larva	W	Dry	0.4-3%
43		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W	Dry	14-31%
44		Moth, spurge hawk- (Deilephila euphorbiae)	Pupa	W	Dry	0.78%
45		Moth, wax (Galleria mellonella)	Pupa	W		0
46		Silkworm (Bombyx mori)	Larva	W	Dry	0.5-1.2%
47	Iodine	Bee, honey (Apis mellifera)	Adult	W	Dry	0.00009%
48		Beetle, forest may- (Melolontha melolontha)	Adult	W	Wet	0.1 %
49		Beetle, water (Hydrous piceus)	Adult	W	Wet	0.08%
50		Fly, house (Musca domestica)	Adult	W	Wet	0.03%
51	Iron	Bee, honey (Apis mellifera)	Adult	W	Dry	0.01%
52		Grasshopper, differential (Melanoplus diff.)	Egg	W	Wet	0.12%
53	Lactic acid	Fly (Gasterophilus spp)	Larva	W	Wet	0.03-0.11%
54	Lipids	Bee, honey (Apis mellifera)	Larva	W	Dry	18.5%
55		Cockroach, American (Periplaneta amer.)	Adult	W	Dry	25.5-28.6%
56		Cockroach, German (Blattella germanica)	Adult	W	Dry	15.6-17%
57		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W	Dry	12.7-26%
58		Fly, tsetse (Glossina morsitans)	Adult	W	Dry	16.2-35.3%
59		Grasshopper, differential (Melanoplus diff.)	Egg	W	Dry	17-22%

	Constituent	Organism	Stage	Tissue		
				Type[1]	Condition	Value[2]
60	Lipids (concluded)	Mealworm, yellow (Tenebrio molitor)	Larva	W	Wet	7.8-15.7%
61		Moth, codling (Carpocapsa pomonella)	Pupa	W	Dry	44%
62		Silkworm (Bombyx mori)	Adult	W	Dry	24%
63	Manganese	Ant, red [Formica rufa]	Adult	H	Dry	0.3%
64		Beetle, water (Gyrinus natator)	Adult	W	Wet	0.0007%
65		Butterfly, Eur. cabbage (Pieris brassicae)	Adult	W	Wet	0.0002%
66		Cricket, Eng. green (Tettigonia viridissima)	Adult	W	Wet	0.0004%
67		Hornet, bald-faced (Vespula maculata)	Larva	GW	Dry	0.13%
68		Locust, desert (Schistocerca gregaria)	Adult	W	Ash	0.16%
69	Nickel	Locust, desert (S. gregaria)	Adult	W	Ash	0.009%
70		Silkworm (Bombyx mori)	Pupa	W		?
71	Nitrogen, amino	Moth, cynthia (Samia cynthia)	Pupa	W	Wet	0.2%
72		Moth, pine hawk- (Sphinx pinastri)	Pupa	W	Wet	0.2%
73		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	W	Wet	0.2%
74	Nitrogen, non-protein	Moth, emperor (Eudia pavonia)	Adult	W	Wet	0.6%
75		Moth, pine hawk- (Sphinx pinastri)	Adult	W	Wet	0.5%
76		Silkworm, Chinese oak (Antheraea pernyi)	Adult	W	Wet	0.8%
77	Nitrogen, total	Bee, honey (Apis mellifera), drone	Adult	W	Dry	11.6%
78		Bee, honey (A. mellifera), worker	Adult	W	Dry	11.5-13.4%
79		Beetle, Japanese (Popillia japonica)	Pupa	W	Wet	1.9-2.9%
80		Caterpillar, east. tent- (Malacosoma amer.)	Adult	W	Dry	9.0%
81		Blowfly (Phaenicia sericata)	Egg	W	Dry	12.5%
82		Silkworm (Bombyx mori)	Larva	W	Wet	0.5-3.3%
83	Phospholipid	Mealworm, yellow (Tenebrio molitor)	Larva	W	Wet	0.6-2.2%
84	Phosphorus, inorganic	Moth, emperor (Eudia pavonia)	Adult	W	Wet	0.01-0.07%
85		Moth, hawk (Deilephila euphorbiae)	Adult	W	Wet	0.11-0.18%
86		Moth, privet hawk- (Sphinx ligustri)	Adult	W	Wet	0.03-0.06%
87		Silkworm, Chinese oak (Antheraea pernyi)	Adult	W	Wet	0.03-0.06%
88	Phosphorus, labile	Moth, hawk (Deilephila euphorbiae) ?	Adult	W		9.2 mg %
89		Moth, hawk (D. euphorbiae) ?	Adult	W		110 mg %
90		Moth, emperor (Eudia pavonia)	Pupa	W	Wet	0.7 mg/g
91	Phosphorus, total	Moth, hawk (Deilephila euphorbiae)	Adult	W	Wet	0.18-0.41%
92		Moth, privet hawk- (Sphinx ligustri)	Pupa	W	Wet	2.7 g/kg
93		Silkworm, Chinese oak (Antheraea pernyi)	Pupa	W	Wet	2.3 g/kg
94	Potassium	Mosquito (Aedes aegypti)	Adult	MG & MT	Dry	15.6 mg/g
95	Reducing substances, as glucose	Beetle, Japanese (Popillia japonica)	Adult		Wet	1.0%
96		Fly, house (Musca domestica)	Adult		Wet	0.8-1.2%
97		Moth, wax (Galleria mellonella)	Larva	W	Wet	0.2-0.3%
98	Silicon[3]	Locust, migratory (Melanoplus mexicanus mex.)	Adult	W	Dry	11.9%
99	Sodium	Mosquito (Aedes aegypti)	Adult	MG & MT	Dry	6.7 mg/g
100	Strontium	Many insects from various families	Adult			+
101	Sulfur	Locust, migratory (Melanoplus mexicanus mex.)	Adult	Fat	Dry	0.02%
102	Titanium[4]	Locust, desert (Schistocerca gregaria)	Adult	W	Dry	0.15%
103	Urea	Silkworm (Bombyx mori)	Egg	W	Wet	24-29 mg %
104		Silkworm, Chinese oak (Antheraea pernyi)	Larva	FB	Wet	29 mg %
105	Uric acid	Blowfly (Phaenicia sericata)	Egg	W	Wet	38 mg %
106		Silkworm (Bombyx mori)	Egg	W	Dry	1.7-3.6 mg/g
107		Silkworm, Chinese oak (Antheraea pernyi)	Larva	FB	Dry	6.7-5 mg/g
108	Water	Beetle, confused flour- (Tribolium conf.)	Pupa	W		59.8%
109		Blowfly (Phaenicia sericata)	Egg	W		79%
110		Cockroach, American (Periplaneta amer.)	Adult	W		61%
111		Cockroach, oriental (Blatta orientalis)	Adult	W		70.6%
112		Fly, blue bottle- (Cynomyopsis cadaverina)	Larva	W		73.3%
113		Fly, horse bot- (Gasterophilus intestinalis)	Larva	W		64.7%
114		Silkworm (Bombyx mori)	Larva	O		75-94%
115		Silkworm, cecropia (Samia cecropia)	Pupa	W		71.8%
116		Weevil, bean (Acanthoscelides obtectus)	Adult	W		48.2%
117	Zinc	Beetle, ground (Carabus auratus)	Adult	W	Wet	0.18 g/kg
118		Fly, house (Musca domestica)	Adult	W		Trace

/1/ FB = fat body; G = gut; H = head; GW = gut wall; MG = midgut; MT = malpighian tubes; O = ovary; HHG = rear hindgut; W = whole. /2/ mg % = mg per 100 g tissue. /3/ As SiO_2. /4/ Per cent of total ash. /5/ As TiO_2.

57. WHOLE ORGANISMS AND HUMAN TISSUES: "B" VITAMIN CONTENT

Values for whole organisms are mg per 100g dry organism, and for human tissues are mg per 100g wet tissue. Ranges represent estimate "d" of the 95% range (cf. introduction). Too much reliance should not be placed on the exact numerical values since incomplete extractions and other limitations are involved in the methods used.

	Organism or Tissue	Biotin	Folic Acid Group[1]	Inositol	Niacin[2]	Panto-thenic Acid	Pyridoxine[3] Group	Ribo-flavin	Thiamine
	THALLOPHYTA								
	Bacteria								
1	Aerobacter aerogenes	0.24-0.39	0.10-0.28	140-160	20-24	14-34	0.7-1.8	4.3	1.1-1.5
2	Azotobacter chroococcum				59.0				3.3-9.6
3	A. vinelandii	0.26-0.42				15.2-18.4		30.5-35.0	
4	Clostridium acidiurici							1.4	
5	C. butyricum	0.17	0.05	86	25	9.2	0.62	5.5	0.93
6	Lactobacillus delbrueckii							11.5	
7	Mycobacterium smegmatis							860	
8	M. tuberculosis							15-20	
9	Phytomonas tumefaciens					4.1			1.2
10	Propionibact. pentosaceum								0.04-0.62
11	Proteus vulgaris	0.34	0.42	100	25	10	0.68		2.1
12	Pseudomonas fluorescens	0.71	0.18	170	21.0	9.0	0.57	6.8	2.6
13	Serratia marcescens	0.41	0.32	160	23.5	12.4	0.11	3.5	2.7
	Fungi								
14	Aspergillus oryzae								1.8
15	Fusarium graminarum								0.5
16	F. lini								2.0
17	Neurospora sitophila						0.91-1.37		
18	Penicillium chrysogenum	0.06-0.15	1.34-1.46		15.0-21.2	10.7-21.2	2.3	3.98-4.75	0.26
19	P. notatum		0.36-0.45		18.0				0.69
20	Mushrooms	0.14		135	54	13.8		2.6	0.88
	Yeasts								
21	Brewer's	0.007		28	12.6	4.2		1.52	0.8
22	Candida arborea	0.03-0.32	1.5-2.0		16.60			4.6-6.9	3.1-3.3
23	Hanseniula suaveolens	0.17	0.17		60	18		9.4	0.8
24	Mycotorula lipolytica	0.18	0.31		60			5.9	0.5
25	Oospora lactis	0.1-0.2	0.6-1.5		19-25			4-5.5	2-2.9
26	Saccharomyces cerevisiae	0.05-0.18	1.9-3.6		19-295	11.8-19.8	1.6-6.5	3.6-7.5	2.9-9
27	Torulopsis utilis	0.11-0.19	0.4-3.1	340-360	21-53	8.6-18	3.5	2.6-6.2	0.6-5.3
	EMBRYOPHYTA								
28	Bean, lima	0.012		180	1.2	0.9		0.14	0.57
29	Peas, black-eyed	0.022		250	1.4	1.1		0.15	0.85
30	Wheat seed	0.006		190	4.5	1.3		0.18	0.55
31	PROTOZOA	0.075		330	9.0	10.5		1.7	3.8
	MOLLUSCA								
32	Oyster	0.053		270	7.3	3.0		1.3	1.1
	ANNELIDA								
33	Earthworm	0.025		52	4.8	1.0		2.5	0.78
	INSECTA								
34	Ant, red	0.037		220	4.7	2.9		1.4	0.73
35	Cockroach	0.048		134	12.0	6.5		2.6	1.62
36	Fly, fruit, larva	0.205		93	21.0	11.6		4.7	2.4
37	Termite	0.066		215	17.5	8.8		2.65	1.28
	VERTEBRATA								
38	Chick[4]	0.175		118	40.5	37.0		1.34	0.83
39	Fish	0.031		88	7.8	2.4		0.52	0.95
40	Frog	0.057		123	5.3	1.7		1.14	0.64
41	Rat	0.033		56	18.0	3.8		1.05	0.50
42	Snake	0.025		107	14.2	2.5		4.5	0.51
43	Toad, horned	0.07		210	17.0	3.6		2.1	1.1
	HUMAN TISSUES								
44	Adrenal	0.035		69	2.4	0.8		0.82	0.16
45	Brain	0.058		151	2.0	1.5		0.25	0.16
46	Colon	0.009		78	1.3	0.5		0.21	0.10
47	Heart	0.017		50	4.1	1.6		0.83	0.36
48	Ileum	0.006		75	1.9	0.53		0.42	0.055
49	Kidney	0.067		124	3.7	1.9		2.0	0.28
50	Liver	0.074		66	5.8	4.3		1.6	0.22
51	Lung	0.019		40	1.8	0.5		0.19	0.15
52	Mammary gland	0.004		27	1.0	0.39		0.24	0.043
53	Ovary	0.0025		58	1.8	0.39		0.43	0.061
54	Seminal ducts	0.0015		<10	0.92	0.20		0.10	0.069
55	Skeletal muscle	0.0035		45	4.7	1.2		0.20	0.12
56	Skin	0.0022		20	0.86	0.31		0.12	0.052
57	Smooth muscle	0.006		58	3.1	0.62		0.23	0.12
58	Spleen	0.006		103	2.3	0.54		0.36	0.11
59	Stomach	0.019		76	1.9	0.61		0.52	0.056
60	Testes	0.009		160	1.6	0.5		0.20	0.08

/1/ Pteroylglutamic acid (folacin), vitamin M, B_c, factor U, L. casei factor, Norite eluate factor. /2/ Nicotinic acid and nicotinamide. /3/ Includes pyridoxine, pyridoxal, pyridoxamine. /4/ Embryo.

Methods by which values have been derived, and units of measurement, are listed numerically at the end of the table and are assigned, by numbers in brackets, to the appropriate enzymes. Values in parentheses are ranges and, unless accompanied by superscript, represent estimate "d" of the 95% range (cf. Introduction).

	Animal	Tissue or Organ	Concentration
		Aconitase [1]	
1	Rat	Brain	10, 0
2	Rat	Intest. mucosa	7, 8
3	Rat	Kidney	80
4	Rat	Liver	61, 5
5	Rat	Lung	14, 5
6	Rat	Salivary gland	11, 9
7	Rat	Testes	7, 6
		Adenosinetriphosphatase [2]	
8	Rat	Brain	7, 0
9	Rat	Cardiac muscle	27, 3
10	Rat	Kidney	20, 3
11	Rat	Liver	12, 9
12	Rat	Lung	21, 8
13	Rat	Pancreas	11, 5
14	Rat	Submaxillary gl.	16, 4
15	Rat	Skel. muscle	23, 3
16	Rat	Spleen	13, 0
		Aldolase [3]	
17	Rabbit	Blood	0, 018
18	Rabbit	Cardiac muscle	0, 62
19	Rabbit	Skel. muscle	7, 5(3, 44-8, 5)
20	Rat	Brain	0, 34(0, 14-0, 72)
21	Rat	Cardiac muscle	0, 62
22	Rat	Kidney	0, 35
23	Rat	Liver	0, 33(0, 18-0, 56)
24	Rat	Skel. muscle	7, 5(3, 44-8, 5)
25	Rat	Spleen	0, 22(0, 10-0, 33)
		Arginase [4]	
26	Mouse	Bone marrow	4, 0
27	Mouse	Brain	3, 0
28	Mouse	Cardiac muscle	7, 0
29	Mouse	Gastric mucosa	4, 0
30	Mouse	Intest. mucosa	80
31	Mouse	Kidney	42
32	Mouse	Liver	246
33	Mouse	Lung	50
34	Mouse	Pancreas	8, 0
35	Mouse	Skel. muscle	4, 0
36	Mouse	Skin	27
37	Mouse	Spleen	6, 0
38	Rat	Brain	3, 0
39	Rat	Kidney	60
40	Rat	Liver	213
41	Rat	Pancreas	4, 0
42	Rat	Skel. muscle	8, 0
43	Rat	Spleen	10, 0
		Asparaginase I [5]	
44	Rat	Brain	1, 0
45	Rat	Kidney	4, 0
46	Rat	Liver	3, 0
47	Rat	Spleen	1, 0
		Asparaginase II [5]	
48	Rat	Brain	0, 0
49	Rat	Kidney	4, 0
50	Rat	Liver	21, 0
51	Rat	Spleen	22, 0
		Carbonic Anhydrase [6]	
52	Cattle	Erythrocytes	10, 9
		Carboxylase, Oxaloacuetic [7]	(0, 2-0, 3)
53	Monkey	Brain	45
54	Ox	Brain	94
55	Swine	Cardiac muscle	840
56	Swine	Kidney	230
57	Swine	Liver	80
58	Pigeon	Breast muscle	740
59	Pigeon	Liver	60
		Carboxypeptidase [8]	
60	Dog	Duodenal fluid	(0, 2-0, 3)
61	Dog	Pancreas	(1, 9-3, 0)
62	G. pig	Duodenal fluid	(0, 2-0, 5)
63	G. pig	Pancreas	(2, 0-4, 5)
64	Man	Duodenal fluid	(0, 2-0, 5)
65	Man	Pancreas	(2, 0-5, 0)
66	Rat	Duodenal fluid	(0, 2-0, 6)
67	Rat	Pancreas	(2, 5-6, 0)
		Catalase [9]	
68	Horse	Erythrocytes	0, 40
69	Horse	Liver	1, 70
70	Man	Erythrocytes	0, 50

	Animal	Tissue or Organ	Concentration
		Choline Acetylase [10]	
71	G. pig	Cardiac muscle	(1, 9, 5
72	G. pig	Kidney	0, 0
73	G. pig	Liver	0, 0
74	G. pig	Skel. muscle	16, 2(10, 5-22, 2)
75	Pigeon	Breast muscle	32, 8(30, 4-34, 4)
76	Rabbit	Cardiac muscle	63(58, 6-67, 3)
77	Rabbit	Sciatic nerve	60
		Dehydrogenase, Alcohol [6]	
78	Horse	Liver	1, 0
		Dehydrogenase, Glutamic Acid [11]	
79	Rat	Brain	10, 3(6, 2-15, 5)[c]
80	Rat	Cardiac muscle	4, 9(0-8, 0)[c]
81	Rat	Kidney	24, 7(19, 3-29, 1)[c]
82	Rat	Liver	49, 3(37, 2-62, 8)[c]
83	Rat	Spleen	15, 2(3, 5-6, 8)[c]
		Dehydrogenase, Isocitric [12]	
84	Mouse	Liver	2, 64
		Dehydrogenase, Lactic Acid [13]	
85	Mouse	Brain	228
86	Mouse	Cardiac muscle	292
87	Mouse	Gastric mucosa	201
88	Mouse	Intest. mucosa	732
89	Mouse	Kidney	367
90	Mouse	Liver	628
91	Mouse	Lymph node	209
92	Mouse	Pancreas	155
93	Mouse	Skel. muscle	972
94	Mouse	Spleen	144
95	Mouse	Testes	206
		Dehydrogenase, Malic Acid [14]	
96	Mouse	Brain	42, 2
97	Mouse	Liver	100(97-103)
98	Pigeon	Skel. muscle	107, 0
99	Rat	Brain	27, 5(27, 2-27, 8)
100	Rat	Kidney	81(70-90)
101	Rat	Liver	103(73-125)
		Dehydrogenase, Succinic Acid [15]	
102	Rat	Brain	19, 2(13, 3-25, 1)
103	Rat	Cardiac muscle	97, 9(78, 1-117, 7)
104	Rat	Kidney	138(99, 7-176)
105	Rat	Liver	66, 4(58, 8-76, 0)
106	Rat	Lung	16, 2(12, 7-19, 7)
107	Rat	Skel. muscle	16, 1(11, 7-20, 5)
		Deoxyribonuclease [16]	
108	Mouse	Bone marrow	7, 0
109	Mouse	Brain	4, 0
110	Mouse	Cardiac muscle	9, 0
111	Mouse	Gastric mucosa	6, 0
112	Mouse	Intest. mucosa	15, 0
113	Mouse	Kidney	10, 0
114	Mouse	Liver	14, 0
115	Mouse	Lung	8, 0
116	Mouse	Lymph nodes	25, 0
117	Mouse	Pancreas	5, 0
118	Mouse	Skel. muscle	12, 0
119	Mouse	Spleen	16, 0
120	Mouse	Thymus	3, 0
		β-p-Glucosidase [17]	
121	Rat	Adrenal	1, 5-3, 0
122	Rat	Brain	2-4
123	Rat	Cardiac muscle	0, 8-1, 6
124	Rat	Intest, large	5, 0
125	Rat	Intest, small	4-6
126	Rat	Kidney	4, 8
127	Rat	Liver	1-3
128	Rat	Pancreas	(0, 2-1, 5)
129	Rat	Salivary gland	(0, 6-2, 5)
130	Rat	Spleen	3-5
131	Rat	Stomach	4, 0
132	Rat	Testes	1-4
133	Rat	Thyroid	8-10
134	Rat	Uterus	1-3
		Esterase, Choline [18]	
135	Rat	Adrenal	2, 5
136	Rat	Brain	5, 5
137	Rat	Cardiac muscle	10, 8
138	Rat	Gastric mucosa	1, 5
139	Rat	Intest. mucosa	6, 5
140	Rat	Liver	0, 9

	Animal	Tissue or Organ	Concentration
		Esterase, Choline [18] (concluded)	
141	Rat	Salivary gland	1, 6
142	Rat	Skin	3, 0
		Esterase, True (Acetylcholine) [19]	
143	Cat	Cer. symp. ga.	28, 4
144	Cat	Sciatic nerve	0, 7
145	Cat	Symp. fiber	3, 7
146	Dog	Brain cortex	(2, 7)
147	Dog	Cer. symp. ga.	14, 0
148	Dog	Lenticular n.	70
149	Dog	Symp. fiber	5, 0
150	Eel, elect.	Elect. org. nnt.	(400-500)
151		Elect. org. pout.	100
152	G. pig	Brain cortex	1, 3
153	G. pig	Cer. symp. ga.	12, 8
154	Ox	Brain cortex	1, 5
155	Ox	Caudate nerve	5, 9
		Fumarase [6]	
156	Swine	Cardiac muscle	0, 02
		β-p-Galactosidase [20]	
157	G. pig	Liver	12, 0
158	G. pig	Spleen	6, 0
159	Mouse	Liver	6, 5
160	Mouse	Spleen	13, 0
161	Rat	Adrenal	20-33
162	Rat	Brain	1, 5
163	Rat	Cardiac muscle	2, 0
164	Rat	Kidney	36, 0
165	Rat	Liver	18, 0
166	Rat	Pancreas	6, 0
167	Rat	Salivery gland	5-11
168	Rat	Spleen	14-20
169	Rat	Thyroid	31-36
170	Rat	Uterus	13-15
		β-Glucuronidase [21]	
171	Rat	Adrenal	4, 6
172	Rat	Kidney	5, 3
173	Rat	Liver	16, 0
174	Rat	Lung	5, 2
175	Rat	Prostate	3, 0
176	Rat	Skel. muscle	0, 1
177	Rat	Spleen	25, 3
178	Rat	Testes	0, 1
179	Rat	Uterus	6, 8
		Hexokinase [22]	
180	Rat	Brain	27, 1(20, 3-31, 2)[c]
181	Rat	Cardiac muscle	14, 5(9, 2-17, 9)[c]
182	Rat	Kidney	7, 9(6, 3-11, 0)[c]
183	Rat	Liver	1, 4(0, 2-2, 6)[c]
184	Rat	Lung	4, 3(2, 9-4, 6)[c]
185	Rat	Pancreas	5, 6(4, 0-7, 4)[c]
186	Rat	Small intestine	11, 7(9, 3-13, 3)[c]
187	Rat	Spleen	8, 3(7, 3-9, 3)[c]
188	Rat	Testes	13, 7(11, 4-18, 8)[c]
189	Rat	Uterus	8, 5(6, 2-10, 9)[c]
		Histaminase [23]	
190	G. pig	Cardiac muscle	1, 30
191	G. pig	Intest. mucosa	1, 54
192	G. pig	Kidney cortex	0, 73
193	G. pig	Liver	1, 88
194	G. pig	Lung	0, 60
195	G. pig	Spleen	0, 44
196	Mouse	Brain	0, 18
197	Mouse	Cardiac muscle	0, 73
198	Mouse	Kidney cortex	1, 30
199	Mouse	Liver	0, 82
200	Mouse	Lung	1, 17
201	Mouse	Spleen	0, 74
202	Swine	Kidney cortex	5, 00
203	Swine	Liver	2, 30
204	Rabbit	Cardiac muscle	21, 20
205	Rabbit	Kidney cortex	4, 80
206	Rabbit	Liver	6, 53
207	Rabbit	Lung	21, 20
208	Rabbit	Spleen	1, 34
209	Rat	Brain	0, 72
210	Rat	Cardiac muscle	2, 52
211	Rat	Kidney cortex	0, 93
212	Rat	Liver	0, 30
213	Rat	Lung	8, 25

[1] The pancreas values are for procarboxypeptidase.

Methods by which values have been derived, and units of measurement, are listed numerically at the end of the table and are assigned, by numbers in brackets, to the appropriate enzymes. Values in parentheses are ranges and, unless accompanied by superscript, represent estimate "of" of the 95% range (cf Introduction).

	Animal	Tissue or Organ	Concentration
		Hyaluronidase [24]	
214	G. pig	Adrenal	1, 3
215	G. pig	Brain	0, 06(0, 04-0, 10)[c]
216	G. pig	Kidney	0, 32(0, 2-0, 55)[c]
217	G. pig	Liver	0, 11(0, 06-0, 15)[c]
218	G. pig	Skel. muscle	0, 12(0, 08-0, 15)[c]
219	G. pig	Spleen	0, 13(0, 08-0, 21)[c]
220	G. pig	Testes	125(100-150)[c]
221	Mouse	Brain	0, 08(0, 07-0, 09)[c]
222	Mouse	Kidney	0, 12(0, 09-0, 16)[c]
223	Mouse	Liver	0, 14(0, 08-0, 20)[c]
224	Mouse	Spleen	0, 13(0, 08-0, 17)[c]
225	Rabbit	Brain	0, 03
226	Rabbit	Kidney	0, 05
227	Rabbit	Liver	0, 07
228	Rabbit	Lung	0, 26
229	Rabbit	Spleen	0, 25
230	Rabbit	Stomach	0, 07
231	Rabbit	Testes	200
		Oxidase, p-Amino Acid [25]	
232	Cat	Kidney	645
233	Cat	Liver	122
234	Dog	Kidney	(680-1100)
235	Dog	Liver	(306-580)
236	G. pig	Kidney	32
237	G. pig	Liver	27
238	Horse	Kidney	23, 0
239	Horse	Liver	22, 0
240	Rat	Kidney	(108-132)
241	Rat	Liver	(15-31)
		Oxidase, L-Amino Acid [6]	
242	Rat	Kidney	0, 20
		Oxidase, Cytochrome-c [26]	
243	Rat	Brain	53
244	Rat	Cardiac muscle	218,
245	Rat	Kidney	157, 9
246	Rat	Liver	62
247	Rat	Lung	22, 9
		Oxidase, Monamine [27]	
248	Man	Cardiac muscle	552
249	Man	Kidney cortex	567
250	Man	Kidney medulla	252
251	Man	Liver	1027
252	Man	Skel. muscle	155
253	Man	Uterus	111
254	Ox	Cardiac muscle	52
255	Ox	Intestine	278
256	Ox	Kidney	6, 55
257	Ox	Liver	796
258	Ox	Spleen	97

	Animal	Tissue or Organ	Concentration
		Oxidase, Monamine [27] (concluded)	
259	Swine	Cardiac muscle	33
260	Swine	Intestine	94
261	Swine	Kidney	435
262	Swine	Liver	257
263	Swine	Pancreas	75
264	Swine	Spleen	14, 0
265	Swine	Thyroid	6, 0
		Phosphoglucomutase [28]	
266	G. pig	Liver	7, 0(5, 5-9, 6)
267	G. pig	Skel. muscle	32, 1(26, 4-41, 9)
268	Rat	Liver	2, 0(6, 5-18, 4)
269	Rat	Skel. muscle	34, 0(30, 7-38, 0)
		Phosphomonoesterase I (Alk. Phosphatase) [29]	
270	Mouse	Bone marrow	23, 0
271	Mouse	Brain	12, 0
272	Mouse	Intest. mucosa	2789
273	Mouse	Kidney	1072
274	Mouse	Liver	4, 0
275	Mouse	Lung	36
276	Mouse	Pancreas	1, 0
277	Mouse	Skel. muscle	2, 0
278	Mouse	Spleen	17, 0
279	Mouse	Submaxillary gl.	23, 0
280	Rat	Brain	4, 0
281	Rat	Kidney	1500
282	Rat	Liver	4, 0
283	Rat	Pancreas	4, 0
284	Rat	Plasma	9, 0
285	Rat	Skel. muscle	2, 0
286	Rat	Spleen	21, 0
		Phosphomonoesterase II (Acid Phosphatase) [30]	
287	Mouse	Bone marrow	22, 0
288	Mouse	Brain	15, 0
289	Mouse	Gastric mucosa	27
290	Mouse	Intest. mucosa	34
291	Mouse	Kidney	15, 0
292	Mouse	Liver	12, 0
293	Mouse	Pancreas	10, 0
294	Mouse	Skel. muscle	19, 0
295	Mouse	Skin	30
296	Mouse	Spleen	73
297	Mouse	Submaxillary gl.	22, 0
298	Rat	Brain	16, 0
299	Rat	Kidney	95
300	Rat	Liver	25, 0
301	Rat	Pancreas	18, 0
302	Rat	Plasma	0, 4
303	Rat	Skel. muscle	16, 0
304	Rat	Skin	8, 0

	Animal	Tissue or Organ	Concentration
		Phosphoprotein Phosphatase [31]	
305	Rat	Adrenals	1, 95(1, 12-3, 08)[c]
306	Rat	Bone marrow	0, 90(0-1, 62)[c]
307	Rat	Cardiac muscle	1, 28(0, 71-1, 70)[c]
308	Rat	Gastric mucosa	1, 74(1, 28-2, 28)[c]
309	Rat	Kidney	2, 43(1, 33-4, 21)[c]
310	Rat	Liver	2, 69(1, 87-3, 76)[c]
311	Rat	Mammary gland	0, 98(0, 84-1, 15)[c]
312	Rat	Pancreas	0, 76(0, 72-0, 82)[c]
313	Rat	Salivary gland	1, 35(0-3, 80)[c]
314	Rat	Spleen	3, 35(0, 93-5, 48)[c]
315	Rat	Testes	2, 03(1, 90-2, 16)[c]
316	Rat	Thymus	2, 46(2, 29-2, 58)[c]
		Ribonuclease [32]	
317	Rabbit	Blood cells	66
318	Rabbit	Blood, whole	78
319	Rabbit	Bone marrow	1, 5
320	Rabbit	Pancreas	2, 4
321	Rabbit	Plasma	16, 0
322	Rabbit	Spleen	4, 7
323	Rat	Blood cells	60
324	Rat	Blood, whole	126
325	Rat	Bone marrow	5, 4
326	Rat	Cardiac muscle	0, 33
327	Rat	Kidney	1, 63
328	Rat	Liver	0, 37
329	Rat	Pancreas	16, 7
330	Rat	Plasma	42
331	Rat	Spleen	2, 06
		Succinoxidase [33]	
332	Rat	Brain	49(41-64)[c]
333	Rat	Cardiac muscle	219(197-250)[c]
334	Rat	Kidney	195(174-226)[c]
335	Rat	Liver	88(79-101)[c]
336	Rat	Lung	17, 9(15, 0-21, 6)[c]
337	Rat	Skel. muscle	35, 5(29, 2-48, 7)[c]
338	Rat	Spleen	23, 3(19, 4-35, 3)[c]
		TPN-Cytochrome-c-Reductase [34]	
339	Mouse	Liver	0, 77
		Transaminase [35]	
340	Rat	Brain	260
341	Rat	Cardiac muscle	425
342	Rat	Kidney	245
343	Rat	Liver	245
344	Rat	Lung	51
345	Rat	Skel. muscle	316
346	Rat	Spleen	16, 0
347	Rat	Testes	150
		Tyrosinase [36]	
348	Mouse	Melanoma	1865

[1] Q citrate formed from cis-aconitate at pH 7, 4 by rat tissue extract. [2] mg of inorganic phosphate split off ATP per mg fresh rat tissue per 15 min (Ca added). [3] mg phosphorus released per min per g of wet tissue(fructose-1,6-diphosphate substrate).[4] Ratio of % hydrolysis of arginine after 2 hr incubation at 38° to the cube root of total N per ml of tissue extract, [5] μM asparagine desminated per ml of tissue extract at pH 8, 4. [6] Grams of purine enzyme per kg whole tissue. [7] mm^3 CO_2 evolved per substrate per hr per mg of protein calculated from the first 5 min of reaction (oxalosuccinic acid substrate). [8] mg of carboxypeptidase per g or ml of fresh tissue homogenate or fluid. [9] Grams catalase per kg wet tissue (H_2O_2 substrate). [10] μg acetylcholine formed per hr per g wet tissue. [11] Q_{O_2} per 10 min per 10 mg of tissue at 38°. [12] μM TPN reduced per min per 100 mg of fresh tissue. [13] Moles x 10^{-8} pyruvate reduced per min per mg total homogenate nitrogen at 26°. [14] μl O_2 consumed per 10 min per 20 mg fresh tissue. [15] Δ log (ferricythrome-c) per min per mg tissue protein. [16] In terms of the decrease in viscosity after $\frac{1}{2}$ hr incubation at 30° of a mixture containing 3 ml of 1% sodium thymonucleate and 3 ml of tissue extract (1, 23 mg N per ml). [17] μg of 6-bromo-2-naphthol produced per hr at 37° with 0, 6 ml of tissue homogenate supernatant. Determined by colorimetric method using 6-bromo-2-naphthyl-β-D-glucopyranoside as substrate. [18] ml CO_2 liberated during hydrolysis of acetylcholine per g fresh rat tissue per hr. [19] mg acetylcholine hydrolyzed by 100 mg tissue per hr at normal temperature and pressure. [20] μg of 6-bromo-2-naphthol produced per hr per 0, 6 ml of tissue homogenate supernatant at 37°. Determined by colorimetric method using 6-bromo-2-naphthyl-β-D-galactopyranoside as substrate. [21] μg phenolphthalein liberated from phenolphthalein glucuronide per mg fresh rat tissue per hr. Determined by colorimetric method. [22] μl of glucose utilized per mg tissue (dry weight) per hr. [23] Expressed as units per g wet tissue; one unit of histaminase activity is defined as the quantity capable of catalysing the release of NH_3 at the rate of 1 μM per 24 hr at 10°. [24] Schering units per g tissue. Activity determined by the "long-time viscosity test" using umbilical cord hyaluronidase as substrate. [25] μl O_2 consumed per hr per 100 mg dry acetone powdered tissue at 37, 5° C. [26] Δ log (ferricythrome-c)per min per mg protein. [27] μl O_2 consumed per hr per g of wet tissue (tyramine substrate). [28] Decrease in acid labile phosphorus in mg phosphorus per hr per g of tissue (Mg activator, glucose-1-phosphate substrate). [29] Average ratio of % hydrolysis of phenyl phosphate after 1 hr incubation at 38° to the total N per ml of tissue extract at pH 9, 5. [30] Average ratio of % hydrolysis of phenyl phosphate after 1 hr incubation at 38° to the total N per ml of tissue extract at pH 4, 6. [31] Enzyme units per mg fresh tissue. An enzyme unit corresponds to the number of μM of phosphorus liberated from casein phosphate per min under experimental conditions. [32] mm^3 CO_2 per min per mg or ml wet tissue (yeast nucleic acid substrate). [33] Q_{O_2} = μl of O_2 taken up in the oxidation of succinate per hr per mg of dry tissue(cytochrome-c and succinate substrate). [34] μM cytochrome-c reduced per min per 100 mg fresh tissue. [35] μl substrate transaminated per hr per mg dry tissue (glutamic acid and oxalacetic acid substrate). [36] μl O_2 consumed per min per g tissue (1 mg tyrosine substrate).

59. CELL SAP: PHYSICAL PROPERTIES

Data applicable to sap of leaves except as otherwise specified.

	Species	Freezing Point Depression °C	Osmotic Pressure, atm	Conductivity mhos x 10^5
1	Aconite (Aconitum porrectum)	1.1-1.2	13.3-14.6	1560-1750
2	Alfalfa (Medicago sativa)	1.4-2.0	16.3-24.1	2040-2940
3	Apple (Pyrus malus)	2-2.3	24-27	1100-1320
4	Apple (P. malus), twig	1.5-1.7	18-20.6	860-950
5	Apple (P. malus), root	0.9-1.4	9.6-11.4	680-1270
6	Asparagus (Asparagus officinalis)	1.5-1.6	18.1-19.1	1800-2050
7	Barley (Hordeum vulgare)	1.4	17.3	2870
8	Bean (Phaseolus sp)	0.9-1.4	11.7	1310
9	Beet (Beta vulgaris)	0.7-1.1	8-13.7	1630-1690
10	Beet (B. vulgaris), root	1.5-1.8	17.7	555
11	Burrowweed (Allenrolfea occidentalis)	3-5.2	36-62	6260-7010
12	Carrot (Daucus carota)	1.2-1.4	13.2-16.7	1940-2360
13	Coffee (Coffea arabica)	1.3	15.5	
14	Columbine (Aquilegia caerulea)	1.2	14.3	1530
15	Corn (Zea mays)	0.9-1.5	11-18.1	960-2210
16	Corn (Z. mays), stem	1-1.4	11.8-16.3	960-2160
17	Corn (Z. mays), root	0.8-1.1	0.9-12.7	2180-2520
18	Cotton (Gossypium barbadense)	1.5-2.2	18.3-27	2950-3160
19	Cotton (G. herbaceum)	1.1-1.5	13.2-19	2880-3370
20	Cotton (G. hirsutum)	1.2	13.8	2020
21	Fig (Ficus carica)	1.2	14.6	
22	Grape (Vitis labrusca)	0.1-1.1	10.7-13	670
23	Grapefruit (Citrus paradisi)	1.5	17.9	1390
24	Greasewood (Sarcobatus vermiculatus)	2-3	25-37	4700-6700
25	Lemon (Citrus limonia)	1.2-2.0	14.4-23.9	1320-1720
26	Lemon (C. limonia), shoot	1.1-1.8	12.8-21.3	
27	Lime (C. aurantifolia)	1.1-1.6	14.1-19	1480-1490
28	Mangrove (Rhizophora mangle)	2.5	30	
29	Maple (Acer grandidentatum), in Utah	1.1-2.2	12.5-27	1030-1690
30	Maple (A. grandidentatum), in Florida		30	860
31	Maple, red (A. rubrum), 12 ft high	1.3	16	940
32	Maple, red (A. rubrum), 27 ft high	1.4	16.4	910
33	Maple, red (A. rubrum) 47 ft high	1.4	16.7	860
34	Mistletoe (Phoradendron juniperinum)	2-2.5	25-30	1960-2370
35	(Host: Juniper (Juniperus utahensis))	1.4-2.3	17.5-28	940-1490
36	Oak, pin (Quercus palustris), 9 ft high	1.7	20.2	1060
37	Oak, pin (Q. palustris), 23 ft high	1.7	20.8	1000
38	Oak, pin (Q. palustris), 33 ft high	1.9	23.2	900
39	Orange (Citrus sinensis)	1.4-2.4	15-22.2	1460-1690
40	Orange (C. sinensis), shoot	1.1-1.7	14.2-20.8	
41	Peach (Prunus persica)	2.2-2.9	25-35	1140-1330
42	Peach (P. persica), twig	1.3-2.2	16.3-25	710-860
43	Peach (P. persica), root	0.7-0.9	8.7-11.6	260-310
44	Poplar (Populus alba) Spring leaves	1.3	15.9	910
45	Summer leaves	1.5	17.8	650
46	Stem bark	1.2	14.6	450
47	Stem tracheae	0.05	0.6	34
48	Root bark	1.1	13.2	380
49	Root tracheae	0.07	0.9	52
50	Potato (Solanum tuberosum)	0.4-0.8	5.2-9	
51	Potato (S. tuberosum), stem	0.6-0.9	7.5-11.3	555
52	Potato (S. tuberosum), tuber	0.4-0.8	5.4-10.3	
53	Sagebrush (Artemisia tridentata)	2.2-4.2	26-50	1000-2400
54	Saltgrass (Distichlis spicata)	1.6-5	19.8-60	2840-9100
55	Sawgrass (Cladium effusum)	0.6-1.1	6.8-13.3	
56	Sorghum (Sorghum vulgare)	0.9-1.1	10.7-13.4	1500-1780
57	Sorghum (S. vulgare), stem	1.2-1.6	14.3-19.7	840-2220
58	Sorghum (S. vulgare), root	1.1-1.8	12.5-21.9	1800-2600
59	Spanish moss (Tillandsia usneoides)	0.5-0.9	6-10.4	
60	Strawberry (Fragaria sp)	2.2	26.8	1750
61	Sunflower (Helianthus annuus), in Arizona	1.4	16.4	2650
62	Sunflower (H. annuus), in Florida	0.7	8.6	1690
63	Sweetclover (Melilotus alba)	1.1-1.7	12.9-20.6	1310-1790
64	Sweetpotato (Ipomoea batatus)	0.9	9.5	1890
65	Tomato (Lycopersicon esculentum	0.8	8.2	
66	Tomato (L. esculentum), root	0.4-1.3	5-15.9	
67	Wheat (Triticum aestivum), entire plant	0.8-2.4	9.6-28	1370-2950

60. XYLEM AND PHLOEM EXUDATION: SQUASH, PUMPKIN

Part I: XYLEM EXUDATION: SQUASH

	Period	Total Sap ml	Rate of Flow ml/plant/min	Dry Matter g/100g	Temp.[1] °C
1	9:15-9:30 A. M.	10.5	0.17	0.16	26.5
2	9:30-9:45 A. M.	28.0	0.47	0.16	
3	9:45-10:00 A. M.	30.0	0.50	0.16	
4	10:00-10:10 A. M.	24.5	0.61	0.15	
5	10:10-10:15 A. M.	10.2	0.51	0.13	
6	10:15-10:20 A. M.	12.0	0.62	0.16	
7	10:20-10:25 A. M.	12.0	0.60	0.18	
8	10:25-10:30 A. M.	12.5	0.62	0.18	
9	10:30-10:35 A. M.	12.5	0.62	0.19	
10	10:35-10:40 A. M.	11.5	0.57	0.22	
11	10:40-10:45 A. M.	10.5	0.52	0.18	
12	10:45-10:50 A. M.	11.0	0.55	0.19	
13	10:50-10:55 A. M.	10.0	0.50	0.20	30
14	10:55-11:00 A. M.	8.5	0.42	0.23	
15	11:00-11:05 A. M.	9.5	0.47	0.21	

/1/ Values applicable to greenhouse. Temp of culture solution, 25°C.

Part II: PHLOEM EXUDATION: SQUASH

	Period	Total Sap		Phloem Area[1]	Rate of Flow[2]	Temp °C
		Fresh Weight g	Dry Weight[1] g	sq cm	cm/hr	
1	2:00-3:00 P. M.	0.788	0.055 (6.9)	0.044	17.9	26.0
2	3:00-4:00 P. M.	0.852	0.042 (4.9)	0.059	14.4	27.0
3	4:00-5:00 P. M.	0.710	0.032 (4.5)	0.060	11.8	22.5
4	5:00-6:00 P. M.	0.596	0.026 (4.4)	0.060	9.9	30.0
5	6:00-7:00 P. M.	0.437	0.019 (4.3)	0.073	6.0	26.0
6	7:00-8:00 P. M.	0.321	0.016 (5.0)	0.077	4.2	21.0
7	8:00-9:00 P. M.	0.499	0.020 (4.1)	0.077	6.5	24.0
8	9:00-10:00 P. M.	0.671	0.024 (3.6)	0.077	8.7	23.5
9	10:00-11:00 P. M.	0.725	0.023 (3.1)	0.084	8.6	24.5
10	11:00-12:00 P. M.	0.584	0.019 (3.3)	0.087	6.7	23.0
11	12:00-1:00 A. M.	0.586	0.018 (3.2)	0.082	7.1	23.5
12	1:00-2:00 A. M.	0.689	0.021 (3.0)	0.082	8.4	25.0

/1/ Dry weight as percentage of fresh weight is enclosed in parentheses. /2/ Determinations based on cross-sectional area of total phloem. Because sieve tubes occupy approximately 25% of the phloem, values must be multiplied by 4 to obtain actual rates.

Part III: COMPOSITION OF PHLOEM EXUDATE FROM FRUITS: PUMPKIN

	Fruit Size[1]	Carbon g/100g	Nitrogen g/100g	Ash g/100g	C:N	Dry Matter g/100g
		Phloem Exudate				
1	A	45	13.2	9.7	3.4	9.4
2	B	44	13.1	8.7	3.4	8.7
3	C	44	13.2	9.1	3.4	10.5
		Fruits				
4	A	43	3.5	10.9	12.2	6.9
5	B	38	2.5	10.1	15.7	5.5
6	C	37	2.6	10.1	14.1	5.1

/1/ Fruit A: length, 10 cm; greatest diameter, 2.7 cm; weight, 43 g. Fruit B: length, 21 cm; greatest diameter, 5.7 cm; weight, 344 g. Fruit C: length 27 cm; greatest diameter, 7.6 cm; weight, 694 g.

61. CELL SAP: pH VALUES

Data applicable to sap of leaves except as otherwise specified.

	Species	pH
1	Aconite (Aconitum porrectum)	5
2	Alfalfa (Medicago sativa)	5.3
3	Apple (Pyrus malus), twig	5.4-6
4	Apple (P. malus), fruit	3.4
5	Asparagus (Asparagus officinalis)	5.8
6	Banana (Musa paradisiaca sapientum), midrib	4.7
7	Barley (Hordeum vulgare)	6
8	Bean (Phaseolus sp)	5.9-6.1
9	Beet, sugar (Beta vulgaris)	6
10	Begonia (Begonia lucerna)	0.9-1.4
11	Boston fern (Nephrolepis exaltata bost.)	5.2
12	Buckwheat (Fagopyrum esculentum)	5.5-5.9
13	Buckwheat (F. esculentum), stem	4.7-5
14	Burroweed (Allenrolfea occidentalis)	5.9-6.6
15	Columbine (Aquilegia caerulea)	4.6-5.3
16	Corn (Zea maya)	5-5.6
17	Corn (Z. maya), stem	5.3-5.7[1]
18	Cotton (Gossypium herbaceum)	5.5-6.8
19	Cranberry (Vaccinium sp), fruit	2.4
20	Garlic (Allium sativum), bulb	3.5
21	Grapefruit (Citrus paridisi), fruit	3
22	Lemon (C. limonia), shoot	5.1-6.1
23	Milo (Sorghum vulgare durra)	4.7
24	Oat (Avena sativa), entire plant	5.6-5.7
25	Olive (Olea europaea), shoot	5.2
26	Onion (Allium cepa)	4.3
27	Orange (Citrus sinensis)	5.8
28	Orange (C. sinensis), shoot	5.3-6.2
29	Orange (C. sinensis), fruit	3.6
30	Oxalis (Oxalis sp)	1.7-2.1
31	Pineapple (Ananas sativus)	4.7
32	Pineapple (A. sativus), fruit	4.4
33	Potato (Solanum tuberosum), tuber	5.6
34	Rape (Brassica napus)	6-6.4
35	Rhubarb (B. campestris napo-brassica), petiole	3.6
36	Sorghum (Sorghum vulgare), entire plant	5.4-5.7
37	Soybean (Glycine soja)	5.8-6.2
38	Soybean (G. soja), stem	5.7-5.8
39	Soybean (G. soja), root	6.3-6.6
40	Sugarcane (Saccharum officinarum)	5.5-5.7
41	Sugarcane (S. officinarum), stem	5.5-6.0
42	Sunflower (Helianthus annuus	6.3-6.9
43	Tobacco (Nicotiana tabacum)	5.3-5.8
44	Tomato (Lycopersicon esculentum)	5.3-5.8
45	Wheat (Triticum aestivum), entire plant	5.6-6.1

/1/ Exuded sap not expressed under pressure, 4.3-4.7.

62. CELL SAP: CHEMICAL COMPOSITION

	Species	Plant Part	Growth Stage	Value mg/100g
	Calcium			
1	Bean, field (Phaseolus sp)	Leaf	Mature	515-690
2		Stem	Mature	137-283
3	Corn (Zea maya)	Stem		4.7-11.6
4	Peanut (Arachis hypogaea)	Lower leaf	Immature	500
5	Potato (Solanum tuberosum)	Lower stem	Mature	100
6	Rye (Secale cereale)	Entire plant		52-59
7	Tomato (Lycopersicon esculentum)	Stem	Immature	18
8	Wheat (Triticum aestivum)	Shoot	Mature	68-106
9		Entire plant	Immature	43
	Magnesium			
10	Bean, field (Phaseolus sp)	Leaf	Mature	42-109
11		Stem	Mature	76-165
12	Beet, sugar (Beta vulgaris)	Leaf	Mature	80-200
13		Stem	Mature	70-130
14	Cabbage (Brassica oleracea cap.)	Stem		6
15	Collard (B. oleracea acephala)	Stem		2.4-7.8
16	Pea, black (Pisum sp)	Petiole		19-42
17	Peanut (Arachis hypogaea)	Lower leaf		290
18	Rye (Secale cereale)	Entire plant	Immature	14-88
19	Tomato (Lycopersicon esculentum)	Stem		6-41
20	Wheat (Triticum aestivum)	Shoot		27-107
21		Entire plant	Immature	39
	Nitrogen as NO_3[1]			
22	Barley (Hordeum vulgare)	Leaf	Mature	20
23		Stem	Mature	23
24	Beet, garden (Beta vulgaris)	Leaf	44-79 da old	3-52
25	Buckwheat (Fagopyrum esculentum)	Shoot		122.6-17.2
26	Cabbage (Brassica oleraces cap.)	Lower leaf	Immature	13-55
27		Stem	Immature	54
28	Carrot (Daucus carota)	Root	2-3 mo old	3-32
29	Celery (Apium graveolens)	Leaf		18-52
30	Collard (Brassica oleracea aceph.)	Stem		13-64
31	Corn (Zea mays)	Lower stem	Mature	4-61
32		Entire plant	Mature	0.5-25
33	Fescue (Festuca elatior)	Entire plant	Immature	1.8
34	Lettuce (Lactuca sativa)	Leaf	Mature	6-45
35	Oat (Avena sativa)	Stem	Mature	41
36	Pea, black (Pisum sp)	Petiole		2-22
37	Potato (Solanum tuberosum)	Lower stem		16.1-18.4
38	Rye (Secale cereale)	Entire plant	Immature	3.8-12.4
39	Soybean (Glycine soja)	Entire plant	Fruiting	2.4-3.6
40	Sugar cane (Saccharum officinarum)	Stem	Mature	10-40[2]
41	Tomato (Lycopersicon esculentum)	Petiole	Fruiting	6.9
42		Stem	Immature	5.8-11.5
43	Wheat (Triticum aestivum)	Shoot	Mature	1-58
44		Entire plant	Immature	2.8
	Phosphorus			
45	Barley (Hordeum vulgare)	Leaf	Mature	6.4-56
46		Stem	Mature	8.9-78
47		Entire plant	36 da old	10
48	Bean, field (Phaseolus sp)	Leaf	Mature	3.5-17.7
49	Beet, sugar (Beta vulgaris)	Leaf	Mature	10.5-250
	Phosphorus (concluded)			
50	Beet, sugar (Beta vulgaris)	Stem	Mature	4.5-24.2
51	Buckwheat (Fagopyrum esculentum)	Leaf		22-105
52		Stem		24-145
53	Cabbage (Brassica oleracea cap.)	Lower leaf	Immature	0.02-1.7
54	Carrot (Daucus carota)	Root	2-3 mo old	0.04-1.0
55	Celery (Apium graveolens)	Leaf	Mature	8.8-17.9
56		Stem	Mature	6-22.8
57	Clover (Trifolium pratense)	Entire plant	82 da old	7.7-21.2
58	Collard (Brassica oleraces aceph.)	Stem		5.8-7.6
59	Corn (Zea mays)	Lower stem	Mature	2.7-3.8
60		Entire plant	Mature	1.6-12.2
61	Fescue (Festuca elatior)	Entire plant	Immature	0.5
62	Pea, black (Pisum sp)	Petiole		1.2-4.4
63	Peanut (Arachis hypogaea)	Lower leaf	Immature	2.3
64	Potato (Solanum tuberosum)	Lower stem	Mature	6
65	Rape (Brassica napus)	Leaf	Immature	15-86
66	Rye (Secale cereale)	Entire plant	Immature	82-112
67	Sorghum (Sorghum vulgare)	Entire plant		90-116
68	Soybean (Glycine soja)	Entire plant	Fruiting	2.6-9.0
69	Sugarcane (Saccharum officinarum)	Stem	Mature	11-19
70	Tomato (Lycopersicon esculentum)	Petiole	Fruiting	30
71		Stem	Immature	12.5-20
72		Shoot	Immature	9.7-19.2
73	Turnip (Brassica rapus)	Root		0-3.4
74	Wheat (Triticum aestivum)	Shoot	Immature	35-81
75		Entire plant	Immature	80
	Potassium			
76	Barley (Hordeum vulgare)	Leaf	Mature	310-860
77		Stem	Mature	260-800
78		Entire plant	36 da old	250
79	Bean, field (Phaseolus sp)	Leaf	Mature	28-200
80	Beet, sugar (Beta vulgaris)	Leaf	Mature	97-516
81		Stem	Mature	340-414
82	Cabbage (Brassica oleraces cap.)	Lower leaf	Immature	112-455
83	Celery (Apium graveolens)	Leaf	Mature	239-418
84		Stalk	Mature	255-408
85	Clover (Trifolium pratense)	Entire plant	82 da old	44-234
86	Collard (Brassica oleraces aceph.)	Stem		160-415
87	Corn (Zea mays)	Lower stem	Mature	166
88		Entire plant		190-650
89	Parsnip (Pastinaca sativa)	Root	3-4 mo old	142-353
90	Pea, black (Pisum sp)	Petiole		250-415
91	Peanut (Arachis hypogaea)	Lower leaf	Immature	500
92	Potato (Solanum tuberosum)	Lower stem	Mature	254-621
93	Rye (Secale cereale)	Entire plant	Immature	579
94	Soybean (Glycine soja)	Entire plant	Fruiting	96-885
95	Sugarcane (Saccharum officinarum)	Stem	Mature	128-266
96	Tomato (Lycopersicon esculentum)	Stem	Immature	200-300
97	Turnip (Brassica rapus)	Leaf		92-425
98		Root		199-343
99	Wheat (Triticum aestivum)	Entire plant	Immature	411

/1/ Values are NO_3-N except as otherwise specified. /2/ Total nitrogen.

63. SHOOTS, LEAVES, SEEDS: MINERAL COMPOSITION

Values are g/100g or mg/kg of specified dry weight material.

	Species	K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
				g/100g					mg/kg		
				Shoots							
	Pandanales; Helobiae										
1	Cattail (Typha angustifolia)	2.0	0.16	1.5	0.1	0.10					
2	Elodea (Elodea canadensis)	1.5-3.0	0.28-0.74	2.9-8.2	0.5-1.2	0.15-0.97					
3	Plantain (Alisma plantago-aquatica)	1.8	0.24	1.0	0.3	0.39					
	Glumiflorae										
4	Barley (Hordeum vulgare)	3.9	0.35	0.7	0.2	0.19	4-53	14	180-540		
5	Bentgrass (Agrostis tenuis)	1.1-3.8	0.15-0.17	0.2-0.9	0.1					296	
6	Bermudagrass (Cynodon dactylon)	1.1-3.0	0.18-0.27	0.4-0.5	0.1-0.3	0.36-0.50	4		150		
7	Bluegrass (Poa pratensis)	1.4-4.3	0.19-0.95	0.1-1.2	0.1-0.2	0.06-0.66	6-12		60-425	29-216	17-28
8	Broomsedge (Andropogon virginicus)	1.2	0.08-0.23	0.3	0.1	0.07					
9	Crabgrass (Digitaria sanguinalis)	3.7	0.30	0.3	0.5	0.17					
10	Fescue (Festuca elatior)	2.4-4.0	0.24-0.37	0.5-0.9	0.1-0.3	0.08-0.17					
11	Johnsongrass (Sorghum halepense)	1.6	0.22	0.4	0.2	0.06					
12	Orchardgrass (Dactylis glomerata)	1.6-4.5	0.19-0.58	0.3-0.8	0.1-0.3	0.06-0.27	5-18			120-370	
13	Redtop (Agrostis alba)	0.7-4.2	0.05-0.41	0.1-1.0	0.1-0.3	0.08-0.33		3-5	56-160	79-510	10-60
14	Rescuegrass (Bromus catharticus)	3.7	0.30	0.2	0.2	0.18		6			14
15	Rye (Secale cereale)		0.23	0.3			0.3-3	7-8			20-21
16	Ryegrass (Lolium perenne)	2.2-4.9	0.28-0.30	0.5-0.9	0.2	0.2	2,9		880		
17	Sedge (Carex acuta)	0.9-1.2	0.12	0.2-1.7	0.1-0.2	0.02-0.13	5[1]		350-680[1]		
18	Sudangrass (Sorghum vulgare sud.)	0.4-2.5	0.16-0.40	0.4-1.2	0.3-0.8	0.05		10	70-140		
19	Timothy (Phleum pratense)	0.8-3.8	0.08-0.60	0.04-1.2	0.03-0.04	0.07-0.32	10-16	2-7	30-287	11-165	30-60
20	Wheat (Triticum aestivum)	2.8	0.32	0.8	0.1	0.11	3-10	3-12	290-580		13-25
21	Velvetgrass (Holcus lanatus)	2.0	0.22	0.4	0.1	0.28	7		140		25
	Spathiflorae; Liliiflorae										
22	Cuckoo-pint (Arum maculatum)	1.4	0.28	2.1	0.5	0.2	9		1620		
23	Asparagus (Asparagus officinalis)	1.4-3.4	0.14-0.78	0.2-1.4	0.1-0.2	0.13-0.26	9-244	7-17	60-979	12-29	52
24	Onion (Allium cepa)	2.6	0.19	2.6	0.3	0.18	4-44				
	Polygonales; Centrospermae										
25	Buckwheat (Fagopyrum esculentum)	1.7-2.6	0.13-0.54	1.7-2.6	0.4-0.6	0.10-0.11	26[2]		100	14	15
26	Sorrell, sheep (Rumex acetosella)	1.4-1.9	0.40-0.49	1.2-2.9	0.5-0.7	0.12					
27	Chickweed (Stellaria media)	3.7	0.40	1.32	1.7	0.14					
28	Corn cockle (Agrostemma githago)	3.1	0.44	2.8	0.5	0.13					
29	Lamb's-quarters (Chenopodium album)	3.5	0.36	2.1	0.4	0.15			158[3]		
30	Purslane (Portulaca oleracea)	10.8	0.48	1.6	1.2	0.27					
31	Saltbush (Atriplex canescens)	0.8	0.05	0.7	0.4	0.28					
	Rhoeadales; Rosales										
32	Celandine (Chelidonium majus)	2.0	0.48	1.5	0.2	0.06	17				
33	Mustard (Brassica hirta)	3.1	0.40	1.8	0.3	0.60	13-54		350		
34	Alfalfa (Medicago sativa)	0.7-4.0	0.15-0.71	0.6-3.5	0.1-1.0	0.19-0.40	12-128	4-61	110-675	10-124	13-112
35	Broadbean (Vicia faba)	2.1	0.27	0.9	0.2	0.14			280	36	
36	Clover (Trifolium incarnatum)	0.7-5.9	0.08-0.53	1.0-1.8	0.2-0.4	0.06-0.40	70		470-1400	24-387	
37	Lespedeza (Lespedeza spp)	1.2-1.4	0.13-0.30	0.9-1.2	0.2-0.3		18-20		126-1028	54-331	
38	Pea, garden (Pisum sativum)	1.7	0.34	1.5	0.5	0.33	17-22			15	
39	Soybean (Glycine soja)	0.5-2.3	0.09-0.74	0.5-2.2	0.2-0.9	0.12-0.52	1-13	4-12	100-570	45-280	28-80
40	Vetch (Vicia sativa)	2.1-2.3	0.13-0.44	1.1-2.0	0.3-0.5	0.27-0.28		10[4]		14-360[1]	
	Malvales; Tubiflorae										
41	Carrot (Daucus carota)	2.4-3.4	0.20-0.29	1.3-1.3	0.2-0.4	0.07-0.48	20-45	5-10	355-765	23-199	26
42	Cotton (Gossypium spp)	0.9-2.1	0.23-0.43	1.0-2.2	0.1-0.7	0.26-0.33	60-795[3]		1754[3]	80-100[3]	
43	Bindweed (Convolvulus arvensis)	2.5	0.77	2.0	0.5	0.19					
44	Bugleweed (Ajuga reptans)	2.4-3.5	0.23-0.76	0.2-1.8	0.3-0.7	0.14-0.43	16		1000-2030		
45	Dodder (Cuscuta europaea)	3.7	0.54	0.2	0.1	1.0					
46	Horsenettle (Solanum carolinense)	1.9	0.98	1.3	1.0	0.48					
47	Mullein (Verbascum thapsus)	3.0	0.19	1.0	0.2	0.21					
48	Peppermint (Mentha piperita)	1.5-2.6	0.19-0.31	0.7-1.9				8-12			
49	Potato (Solanum tuberosum)	0.03-4.2	0.08-0.26	0.6-4.1	0.2-1.2	0.15-0.68	14-39	11		86-108	
	Plantaginales; Campanulatae										
50	Plantain (Plantago lanceolata)	2.6	0.27	1.2	0.2	0.33					
51	Bellflower (Campanula patula)	2.4	0.25	0.8	0.3	0.16					
52	Dandelion (Taraxacum officinale)	4.4	0.49	1.0	0.3	0.22	14	13[3]	440	193	98-101[3]
53	Ragweed (Abrosia artemisiifolia)	1.9	0.25	1.8	0.5	0.23			190		17-65
				Leaves							
	Glumiflorae; Principes										
54	Sugar cane (Saccharum officinarum)	0.4-2.5	0.07-0.98	0.1-0.6	0.04-0.6	0.06-0.23			370	30	
55	Date (Phoenix dactylifera)	0.2-1.6	0.06-0.19	0.3-1.1	0.1-0.2		73-172				
	Salicales; Juglandales										
56	Aspen, European (Populus tremula)	1.4	0.34	3.1	0.2	0.10					
57	Pecan (Carya illinoensis)	0.3-0.9	0.10-0.15	1.1-1.6	0.4			21-28	144-185		4-202
58	Walnut, black (Juglans nigra)	2.0-2.4	0.32-0.54	1.3-3.2	0.4-0.5	0.01-0.23	40-67	11	280-780	60-190	26-49
	Fagales; Urticales										
59	Hornbeam (Carpinus betulus)	0.5	0.2	2.3	0.1	0.04					
60	Oak, black (Quercus velutina)	1.0-1.2	0.15-0.20	0.9-2.2	0.3-0.4	0.04-0.25		7-9	250-280	490-1870	38-68
61	Elm, American (Ulmus americana)	0.6-2.0	0.13-0.59	1.4-2.4	0.4-0.6	0.02-0.35	277	7-16	245-810	39-130	10-22
62	Fig (Ficus carica)	1.0	0.21	1.2	0.7	0.08	245-1349				
63	Hackberry (Celtis occidentalis)	1.7-2.3	0.16-0.44	2.5-7.8	0.4-0.5	0.17-0.29		6-8	550-730	100-170	6-32
64	Mulberry, red (Morus rubra)	2.3	0.29	3.8	0.4	0.09		7	500	250	30
65	Nettle (Urtica dioica)	2.2	0.80	4.6	0.9	0.76					
66	Ramie (Boehmeria spp)	0.7	0.41	4.9	0.8	0.15					
	Santalales; Ranales										
67	Mistletoe (Viscum album)	0.1-2.3	0.25-0.77	0.9-1.7	0.3-0.7	0.08-0.26					
68	Magnolia, bigleaf (Magnolia macrophylla)	1.2-3.3	0.18-0.48	0.1-2.4	0.3-0.4	0.02-0.29		6-8	150-230	29-30	19-62
69	Waterlily (Nymphaea alba)	1.1-1.6	0.15-0.22	1.8-2.2	0.2-0.3	0.06-0.07					
70	Yellow-poplar (Liriodendron tulipifera)	0.9-1.7	0.20-0.36	1.2-1.5	0.2-0.3	0.26-0.38		3-5	240-380	40-90	26-68

/1/ Applicable to various species. /2/ Applicable to stems. /3/ Applicable to leaves.

63. SHOOTS, LEAVES, SEEDS: MINERAL COMPOSITION (Concluded)

Values are g/100g or mg/kg of specified dry weight material.

	Species	K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
		g/100g					mg/kg				
	Leaves (concluded)										
	Rosales										
71	Apple (Pyrus malus)	0.5-3.9	0.09-0.75	0.6-2.7	0.1-0.8		11-43	3-12	65-507	20-156	4-345
72	Blacklocust (Robinia pseudoacacia)	1.2-2.1	0.20-0.56	1.5-4.5	0.3-0.4	0.02-0.39	30-70	7	190-330	40-50	7-50
73	Cherry, black (Prunus serotina)	1.1-1.3	0.14-0.47	1.3-2.4	0.4-0.6	0.06-0.21	104[1]	6-8	210-290	170-230	27-72
74	Crabapple (Malus coronaria)	1.4-1.8	0.34-0.56	1.5-1.9	0.2-0.3	0.16-0.21		8-9	180-300	20-30	7-52
75	Peach (Prunus persica)	0.8-2.4	0.09-0.72	1.1-2.7	0.4-1.4		17-81			17-325	6-345
76	Peanut (Arachis hypogaea)	4.2	0.26	2.1	0.7						
77	Pear (Pyrus communis)	0.8-2.2	0.11-0.16	1.2-3.0	0.3-0.4			5-41	28-94		
78	Sweetgum (Liquidambar styraciflua)	0.6-1.6	0.17-0.37	0.8-2.0	0.4-0.5	0.01-0.26	19-29	9-15	200-740	310-700	2-27
79	Sycamore (Platanus occidentalis)	1.2-1.6	0.15-0.46	1.4-2.2	0.3	0.08-0.42		4-7	180-260	120-150	9-42
80	Yellow-wood (Cladrastis lutea)	1.8-2.4	0.42-0.78	1.8-3.7	0.2-0.3	0.11-0.25		7-12	180-360	30-70	11-60
	Geraniales; Sapindales; Rhamnales										
81	Flax (Linum usitatissimum)	1.3-2.3	0.34-0.45	0.9-1.2	0.3-0.6	0.15-0.38	7-24[4]	3-4[4]			20-28[4]
82	Holly, American (Ilex opaca)	0.7-2.0	0.07-0.40	0.5-1.4	0.3-0.5	0.21-0.33		6-14	200-270	260-540	130-240
83	Maple, sugar (Acer saccharum)	1.0-1.6	0.24-0.46	0.6-2.4	0.2-0.4	0.01-0.24		11-12	150-440	40-220	24-54
84	Tung (Aleurites fordii)	0.6-2.9	0.13-0.50	0.6-4.9	0.2-0.6		15-125	4-15	41-375	22-2884	16-229
85	Buckeye, Ohio (Aesculus glabra)	0.9-2.6	0.28-0.61	1.6-4.4	0.3-0.5	0.15-0.31		5-7	340-500	70-120	28-35
86	Grape, riverbank (Vitis vinifera)	0.6-1.0	0.08-0.20	1.8-2.8	0.2-0.4	0.10-0.11	16-208[4]	3-47[4]	190-220[4]	180-220[4]	
	Malvales; Umbelliflorae; Ebenales										
87	Basswood, American (Tilia americana)	1.1-2.5	0.22-0.62	1.4-6.4	0.4-0.8	Tr-0.34		8-10	220-430	7-210	21-54
88	Dogwood, flowering (Cornus florida)	0.4-1.1	0.18-0.32	2.7-4.2	0.3-0.5	0.38-0.70	23	7-9	240-380	30-50	3-28
89	Ivy, English (Hedera helix)	1.0	0.26	3.6	0.2	0.28					
90	Persimmon (Diospyros virginiana)	2.0-2.4	0.14-0.46	0.6-1.8	0.3-0.5	0.27-0.28		5-8	210-250	90-220	36-48
	Oleales; Tubiflorae										
91	Ash, blue (Fraxinus quadrangulata)	1.3-2.0	0.35-0.61	0.6-2.0	0.3-0.4	0.11-0.39		11-16	250-330	60-80	12-34
92	Lilac (Syringa vulgaris)	0.9-1.0	0.20-0.54	0.5	0.2	0.01-0.05	4-8[1]		110-700[1]		
93	Olive (Olea europaea)	0.5-1.1	0.12-0.30	0.8-1.9	0.1-0.2	0.02-0.05	7-44		250-880		
94	Belladonna (Atropa belladonna)	2.8	0.37	1.2	0.4	0.26					
95	Catalpa (Catalpa speciosa)	1.3-2.5	0.30-0.58	1.2-2.3	0.3-0.5	0.22-0.48		18-21	330-680	80-130	28-50
96	Sweetpotato (Ipomoea batatas)	1.6-2.4	0.19-0.28	0.7-1.2	0.4-0.5						
	Rubiales; Campanulatae										
97	Cinchona (Cinchona ledgeriana)	0.8-1.2	0.20-0.49	0.4-0.7	0.2-0.3						
98	Coffee (Coffea arabica)	2.7	0.16	0.9	0.2	0.08					
99	Aster (Aster amellus)	3.5	0.16	2.5	0.3	0.25					
100	Guayule (Parthenium argentatum)	4.0-7.7	0.30-0.36	2.4-5.1	0.8-1.4	1.46-1.65					
	Seeds										
	Glumiflorae; Fagales										
101	Barley (Hordeum vulgare)	0.3-0.9	0.15-0.62	0.01-0.2	0.02-0.3	0.02-0.37	0.6-13	1-70	14-350	7-38	21-132
102	Bluegrass, Kentucky (Poa pratensis)	0.7	0.85	0.3	0.2	0.20		60	350-460	85-110	360
103	Millet (Panicum miliaceum)	0.3	0.29	0.02	0.2	0.003					
104	Rice (Oryza sativa)	0.2-0.5	0.19-0.43	0.05-0.1	0.1-0.2	0.001-0.14	9.4	3-4	76-350	18-70	30
105	Rye (Secale cereale)	0.5-0.6	0.21-0.52	0.04-0.2	0.1-0.2	0.01-0.41	2-9	2-7	57-700	32-157	13-73
106	Ryegrass (Lolium italicum)	0.5	0.54	0.5	0.2	0.31					
107	Sorgo (Sorghum vulgare)	0.3	0.29-0.41	0.01-0.1	0.2	0.01					
108	Timothy (Phleum pratense)	0.5	0.35	0.2	0.1	0.03			61-410	72	
109	Wheat (Triticum aestivum)	0.2-1.0	0.10-0.54	0.01-0.30	0.1-0.3	0.003-0.29	1.11	3-24	3-420	5-260	19-105
110	Beech, European (Fagus sylvatica)	1.0-1.2	0.44-0.49	0.3-0.5	0.2-0.3	0.08-0.09					
111	Chestnut (Castanea sativa)	0.7	0.17	0.1	0.1	0.09					
	Centrospermae; Ranales; Rhoeadales										
112	Beet (Beta vulgaris)	1.0	0.44	0.9	0.5	0.10					
113	Waterlily (Nymphaea tetragona)	1.4	0.73	0.2	0.2						
114	Mustard (Brassica hirta)	0.6	0.73	0.6	0.2	0.08	12		290		
115	Poppy, opium (Papaver somniferum)	0.5-0.7	0.82-0.89	1.3-1.6	0.3-0.4	0.05-0.10					
116	Radish (Raphanus sativus subsp. sativus)	0.7	0.87	0.6	0.1	0.07					
117	Rape (Brassica napus)	0.9	0.82	0.4	0.3	0.04	11		85-480	38	
	Rosales; Geraniales										
118	Apple (Pyrus malus)	0.8	0.71	0.2	0.4	0.05					
119	Almond (Prunus amygdalus)	0.2-1.1	0.44-0.93	0.2-0.3	0.2-0.5	0.01-0.05	15-57	11-13	42-190	13	21
120	Bean (Phaseolus vulgaris)	1.2-1.9	0.41-0.50	0.1-0.2	0.15-0.20	0.05-0.23	17		120	20	
121	Bean, mung (P. aureus)	0.6-1.2	0.31-0.58	0.3-0.6	0.2	0.02					
122	Broadbean (Vicia faba)	1.2-1.3	0.58-0.62	0.1	0.1-0.2	0.05-0.09	11-223	10-11	21	14-15	
123	Chick pea (Cicer arietinum)	0.7	0.57	0.1	0.4	0.04	14	7	560	29	19
124	Cowpea (Vigna sinensis)	1.3-1.8	0.36-0.74	0.1-0.2	0.2-0.3	0.28		5-7	67-662	45	
125	Lupine (Lupinus spp)	0.8	0.48	0.2	0.2	0.12			210	678	
126	Pea, garden (Pisum sativum)	0.8-1.0	0.38-0.61	0.06-0.11	0.1-0.2	0.04-0.16	2-8	6-15	70-282	4-25	40-48
127	Plum (Prunus domestica)	0.9	0.62	0.2	0.4	0.12					
128	Soybean (Glycine soja)	0.8-2.4	0.50-1.80	0.1-0.3	0.2-0.3	0.002-0.45	6-41	12-23	57-161	14-41	18
129	Vetch (Vicia sativa)	0.8-1.1	0.50-0.53	0.1-0.2	0.2	0.04-0.14				14-72[1]	
130	Flax (Linum usitatissimum)	0.6-0.9	0.43-0.85	0.2-0.3	0.3-0.4	0.03-0.06	11-17		85-118	38-102	20
131	Orange (Citrus aurantium)	0.9-1.0	0.29-0.45	0.4-0.5	0.1-0.2	0.03-0.06					
	Rhamnales; Malvales; Opuntiales										
132	Grape, riverbank (Vitis vinifera)	0.6-0.7	0.33-0.34	0.4-0.7	0.1	0.04-0.07					
133	Cacoa (Theobroma cacao)	0.9	0.53	0.1	0.2	0.04					
134	Cotton (Gossypium hirsutum)	0.9-1.9	0.48-1.79	0.4-0.3	0.2-0.4	0.05-0.76	27-130[1]	54[1]	150-590[1]	13-31[1]	320[1]
135	Prickly pear (Opuntia compressa)	0.2	0.003	0.5	0.2	0.001					
	Oleales; Tubiflorae										
136	Olive (Olea europaea)	0.7	0.38	0.1	0.02	0.03	3				
137	Sesame (Sesamum indicum)	0.5	0.66	1.2	0.4	0.02					
138	Tobacco (Nicotiana tabacum)	1.3	0.62	0.2	0.3	0.02	6[1]		240[1]	70[1]	
	Rubiales; Cucurbitales										
139	Coffee (Coffea arabica)	1.7-1.9	0.22-0.38	0.1-0.2	0.2	0.05-0.06	8-17	8-20	150-280	14-32	
140	Watermelon (Citrullus vulgaris)	0.7	0.48	0.04	0.1	0.03					

/1/ Applicable to various species. /4/ Applicable to shoots.

64. PLANT TISSUES AND ORGANS: MINERAL COMPOSITION

Values are g/100 g or mg/kg dry weight material, as specified in column headings.

	Species	Plant Part[1]	K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
			g/100 g					mg/kg				
1	Carnation (Dianthus caryophyllus)	Leaves	1.4	0.21	0.9	0.2	0.08					
2		Stems	1.0	0.24	1.7	0.2	0.14					
3		Roots	1.1	0.28	1.8	0.2	0.06					
4		Petals	2.5	0.36	0.2	0.1	0.09					
5	Clover, red (Trifolium pratense)	Leaves	1.8-2.0	0.23-0.34	2.0-2.8	0.5-0.7	0.04-0.05	57			40-84	
6		Petioles	2.6	0.48	2.2	0.6	0.06					
7		Stems	1.7-2.0	0.12-0.32	1.1-1.3	0.4-0.5	0.04-0.06	28			15-20	
8		Shoot, veg.	2.2-3.0	0.32-0.53	1.9-2.0	0.5-0.6	0.09	23-58	6-20[2]	100-1300	25-542[2]	24-80[2]
9		Shoot, fl.	1.1-3.4	0.21-0.29	1.1-2.1	0.4-0.7	0.09-0.19	19-109			287	
10		Shoot, fr.	1.0-1.8	0.23-0.39	1.9-2.0	0.5-0.6	0.06-0.16				465	
11		Flowers	1.5-2.1	0.38-0.50	1.2	0.4-0.5	0.06	40			30-66	
12		Seed	1.3	0.75	0.2	0.4	0.04		17	21-336	6-38	76
13	Corn (Zea mays)	Leaves	0.2-1.6	0.05-0.26	0.1-0.9	0.2-0.3	0.23-0.25	27-72		41-810	230-440	
14		Stems	0.3-2.4	0.03-0.20	0.1-0.6	0.1-0.3	0.05-0.17			400-740	100-230	
15		Shoot, veg.	6.2-9.9	0.21-0.39	0.6-0.7	0.3	0.32-0.42	15-18[2]	2-9[3]	312-321[2]	52-200[2]	5-80[3]
16		Shoot, fl.	1.7-7.1	0.14-0.55	0.6-0.7	0.2-0.4	0.08-0.37					
17		Shoot, fr.	0.3-1.9	0.04-0.42	0.1-0.8	0.1-0.5	0.08-0.31					
18		Roots	0.3-1.3	0.03-0.14	0.1-0.7	0.1-0.2	0.03-0.28			500-760	450-880	
19		Flowers, ♂	1.3	0.15	0.57	0.27						
20		Flowers, ♀	1.5	0.15	0.63	0.34						
21		Cob	0.5	0.09	0.02	0.1	0.02			250	310	
22		Kernel	0.2-0.9	0.23-0.80	0.01-0.06	0.1-0.3	0.004-0.30	1.9	4-30	13-550	5-500	20
23	Cotton (Gossypium hirsutum)	Leaves[4]						60-795		1754	80-100	
24		Stems[4]						6-186		610	40-50	
25		Shoot, veg.	2.6-3.3	0.30-0.33	0.2-2.8	0.5-1.3						
26		Shoot, fr.	1.0-1.5	0.17-0.20	1.4-1.5	0.4-0.6						
27		Burs	1.4-5.7	0.07-0.21	0.4-1.0	0.2-0.3						
28		Lint	0.5-0.8	0.02-0.12	0.01-0.27	0.1	0.04-0.06			190	11-190	
29		Seed	0.9-1.9	0.48-1.79	0.1-0.3	0.2-0.4	0.05-0.76	27-130	54	150-590	13-31	320
30	Horsechestnut (Aesculus hippocastanum)	Leaves	3.2	0.82	5.7	0.2	0.08					
31		Petioles	4.3	0.72	1.7	0.2	0.17					
32		Bark	0.5	0.13	2.7	0.05						
33		Wood	0.2	0.07	0.2	0.02						
34		Peduncle	5.0	0.70	0.6	0.07	0.13					
35		Calyx & ovaries	2.7	0.38	0.5	0.2	0.08					
36		Stamen	2.6	0.44	0.5	0.1						
37		Petals	2.4	0.35	0.5	0.1						
38		Bracts	1.5	0.65	1.4	0.1	0.24					
39		Fruit						11		Trace		
40		Seed	1.1-1.2	0.22-0.31	0.06-0.1	0.1	0.02-0.03					
41	Oat (Avena sativa)	Shoot, veg.	2.8-2.9	0.24-0.36	0.4-0.5	0.1-0.2	0.14-0.17		4-12		79-90	18-40
42		Shoot, fr.	2.0-2.2	0.21-0.48	0.3-0.7	0.1-0.3	0.07-0.57	15-50	3-4	50-270	5-82	12-25
43		Shoot, fr.	0.8-2.2	0.16-0.40	0.2-0.5	0.1-0.4	0.07-0.28	2-17	1-9	154	9-116	12-13
44		Roots										19-550
45		Straw	0.6-3.5	0.02-0.36	0.2-0.7	0.1-0.5	0.08-0.51	8	2-54	61-860	4-1656	4-193
46		Seed	0.3-1.1	0.15-0.96	0.02-0.19	0.1-0.4	0.02-0.29	1-19	0.7-51	7-350	14-76	22-40
47	Orange (Citrus sinensis)	Young lvs.	1.6	0.18	4.3	0.1	0.23					
48		Old lvs.	0.1	0.11	8.2	0.1	0.26	17-386[2]	7-18	38-345	24-46	24-47[2]
49		Twig bark	0.6	0.28	5.2	0.1	0.27					
50		Twig wood	0.2	0.22	1.3	0.1	0.12					
51		Trunk bark	0.7	0.24	4.4	0.4	0.18					
52		Trunk wood	0.2	0.16	0.7	0.1	0.11					
53		Root bark	0.8	0.24	3.3	0.2	0.20					
54		Root wood	0.2	0.16	0.7	0.1	0.08					
55		Small roots	0.16-1.25	0.25	0.4-0.5	0.2-0.8	0.14	95[2]				240[2]
56	Sunflower (Helianthus annuus)	Leaves	1.6-1.9	0.24-0.35	3.3-7.6	1.1-3.2	0.43-0.66	43-728				
57		Petioles	0.8	0.12	1.5	0.6	0.09					
58		Upper stems	2.5	0.13	0.7	0.2	0.09					
59		Lower stems	1.4	0.09	0.5	0.2	0.17					
60		Roots	1.4-3.8	0.10-0.34	0.4-2.2	0.1-1.3	0.34	30-77				
61		Flowers	1.6	0.41	0.8	0.3	0.08					
62		Fruits	1.0-3.2	0.32-0.50	0.3-1.0	0.2-0.3	0.19			34	23	19
63		Fruit coats	0.9	0.07	0.4	0.2	0.05					
64		Head minus fr.	9.4	0.41	2.5	1.3	0.46					
65		Seed	1.0	1.01	0.1-0.2	0.4	0.02					
66	Tomato, Pan America (Lycopersicon)[5]	Leaves, veg.	4.9	1.06	4.2	0.8		21-150[2]	12-21[2]	106-840[2]	53-4930[2]	17-305
67		Leaves, early fl.	5.8	1.07	4.1	0.8						
68		Leaves, fl.	3.3	0.63	3.4	0.5						
69		Leaves, early fr.	2.5	0.59	3.1	0.5						
70		Leaves, mid-fr.	1.8	0.46	4.2	0.6						
71		Stems, veg.	10.7	0.63	3.2	0.8		21-26[2]	6-13	110-230	14-45[2]	
72		Stems, early fl.	10.2	0.78	3.2	0.9						
73		Stems, fl.	3.8	0.59	1.6	0.4						
74		Stems, early fr.	2.2	0.55	1.7	0.3						
75		Stems, mid-fr.	1.3	0.43	1.8	0.4						
76		Roots, veg.	5.1	0.71	1.4	0.6						
77		Roots, early fl.	5.5	0.85	1.5	0.7						
78		Roots, fl.	2.1	0.98	1.7	0.5						
79		Roots, early fr.	2.2	1.08	1.9	0.7						
80		Roots, mid-fr.	1.4	1.18	2.8	0.5						
81		Fruits	4.0	0.74	0.4	0.1		13-36	4-34	32-800	2-410	2-67

/1/ Veg. = plants in vegetative condition; fl. = plants flowering; fr. = plants fruiting. Shoots are stems with terminal buds and leaves. /2/ Value from unspecified condition of growth. /3/ Value for stover (mature cured stalk, without ears). /4/ Values for Hirsutum sp. /5/ Value for leaflets. /6/ L. esculentum x L. pimpinellifolium.

65. SEEDS: CHEMICAL COMPOSITION

Values, except as otherwise indicated, are g or mg per 100g seeds.

	Species	Gross Composition					Amino Acids										Fatty Acids				Vitamins		
		Water	Protein	Fat	Carbohydrate	Ash	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Niacin	Pantothenic Acid	Riboflavin	Thiamine
		g/100g																g/100g fat[1]					mg/100g			
1	Barley (Hordeum vulgare)	11.1	8.2	1.0	78.8	0.9	0.61	0.26	0.51	0.84	0.42	0.19	0.62	0.48	0.19		0.61	9	3	33	54		3.1	0.66	0.08	0.12
2	Bean, lima (Phaseolus vulgaris mac.)	12.6	20.7	1.1	61.6	3.8																	2.0	0.84	0.18	0.48
3	Bean, mung (P. aureus)	9.8	23.3	1.0	62.0	3.9	0.30	0.21	0.12	3.2	0.74	0.25	1.2	0.60	0.17	0.66	1.9	28	8	18	40	3	2.0		0.21	0.68
4	Chick-pea (Cicer arietinum)	10.6	20.8	4.7	60.9	3.0																	1.6		0.18	0.49
5	Corn (Zea mays)	13.0	8.9	4.7	73.0	1.2	0.45	0.24	0.36	1.1	0.29	0.21	0.46	0.34	0.08		0.50	10.2	3.0	50	34		2.8	0.64	0.10	0.49
6	Cotton (Gossypium hirsutum)[2]	7.3	23.1	22.9	43.2	3.5	3.0	1.1	1.8	2.2	1.5	0.5	2.2	1.1	0.4	0.6	1.8	◄ 27 ►		19	54		4.4		0.31	
7	Cowpea (Vigna sinensis)	10.6	22.9	1.4	61.6	3.5																	2.2		0.16	0.92
8	Flax (Linum usitatissimum)[2]	6.2	24.0	35.9	30.3	3.6	3.6	0.65	1.8	2.3	1.4	0.35	2.2	1.3	0.63		2.2									
9	Gingko (Gingko biloba)	7.3	7.2	1.6	41.2	1.7																				
10	Hemp (Cannabis sativa)	7.0	28	37														◄ 10.1 ►		16	46	28				
11	Lentil (Lens culinaris)	11.2	25.0	1.0	59.5	3.3																	2.2		0.24	0.56
12	Lotus (Nelumbium nelumbo)	9.6	16.5	2.3	63.9	3.6																				
13	Oat (Avena sativa)	9.8	12.0	4.6	69.6	4.0	0.99	0.23	0.80	0.87	0.51	0.23	0.72	0.54	0.20	0.50	0.99	10		59	31		1.0	0.63	0.13	0.92
14	Pea (Pisum sativum)	11.6	23.8	1.4	60.2	3.0	2.6	0.4	1.2	1.9	1.5	0.1	1.4	1.2	0.2		1.2						3.1	1.01	0.28	0.77
15	Peanut (Arachis hypogaea)[2]	4.0	26.2	42.8	24.3	2.7	6.9	1.3	2.6	4.1	1.9	0.6	3.1	1.6	0.8		2.8	6.3	4.9	61	21.8		15.6	3.50	0.13	1.09
16	Pigeon-pea (Cajanus cajan)	13.1	21.9	1.6	59.9	3.5																	2.0		0.18	0.47
17	Popcorn (Zea mays praecox)	9.8	11.9	4.7	72.1	1.5																	2.1		0.11	0.39
18	Pumpkin (Cucurbita pepo)	2.4	22.9	31.9	13.2	3.6																	1.5		0.10	0.18
19	Rape (Brassica napus)	9.5	20.4	43.6	22.3	4.2												1		32	15					
20	Rice (Oryza sativa)	12.0	7.5	1.7	77.7	1.1	0.54	0.14	0.28	0.51	0.28	0.14	0.31	0.22	0.10		0.40	13.2	1.9	44	39		4.6	1.01	0.05	0.32
21	Rye (Secale cereale)	11.0	12.1	1.7	73.4	1.8	0.59	0.25	0.44	0.67	0.45	0.18	0.47	0.37	0.14		0.56	◄ 2 ►		18	61		1.6	0.92	0.22	0.43
22	Safflower (Carthamus tinctorius)	6.0	12.7	30.8		3.0												◄ 5.8 ►		16	78					
23	Sesame (Sesamum indicum)	5.8	19.3	51.1	18.1	5.7																	4.5		0.22	0.93
24	Sorghum (Sorghum vulgare)	10.0	11.2	3.5	73.8	1.5												8.5					4.5	1.04	0.13	
25	Soybean (Glycine soja)[2]	7.5	34.9	18.1	34.8	4.7	4.1	1.3	2.6	4.3	3.1	0.5	3.1	2.3	0.7		2.7	◄ 15 ►		27	52	6	2.3	1.56	0.31	1.07
26	Sunflower (Helianthus annuus)[2]	5.0	18.5	27.8		3.3	5.46	1.43	2.78	3.71	1.45	1.61	2.39	1.64	1.14		2.70	◄ 11.3 ►		30	60					
27	Wheat (Triticum esculentum)	12.5	12.3	1.8	71.7	1.7	0.63	0.31	0.58	0.91	0.35	0.22	0.70	0.38	0.19		0.64	13.8	1.0	30	49	6	4.3	1.39	0.12	0.52

/1/ Component fatty acids are expressed as per cent by weight of the total fatty acids of the seed. /2/ Values for amino acids are applicable to meal or flour.

66. POLLEN: PROXIMATE CHEMICAL COMPOSITION

Data applicable to bee-collected pollen except for species indicated by an asterisk (*). Bees add reducing sugars, such as honey or nectar, when collecting pollen. Values are g per 100 g pollen.

	Species	Water	Protein	Fat	Starch	Reducing Sugar	Non-reducing Sugar	Ash
		g/100g pollen						
1	Almond (Prunus amygdalus)	9.8	28.7	3.2	0.7	24.4	3.1	2.6
2	Asparagus (Asparagus officinalis)	10.7	25.6	4.1	1.4	20.0	4.6	4.4
3	Bermuda grass (Cynodon dactylon)	13.3	20.4	2.4	0.4	25.5	3.4	3.1
4	Birch brush (Cesnothus integerrimus)	10.1	26.1	0.9	0	19.6	4.8	3.1
5	Buckthorn (C. crassifolius)	8.1	29.9	1.2	2.0	23.5	3.7	3.1
6	Cattail (Typha latifolia)*	6.4	18.8	1.3	13.0	0.04	18.9	3.8
7	Chamaebatia (Chamaebatia foliolosa)	15.7	23.4	4.2	2.8	27.7	0	2.6
8	Clover (Trifolium sp)	13.4	20.7	3.2	7.8	20.0	2.4	5.5
9	Clover, Ladino (T. repens)	11.6	23.7	3.4	1.3	21.4	4.2	3.1
10	Corn (Zea mays)*	5.5	20.3	3.7	22.4	6.9	7.3	2.6
11	Dandelion (Taraxacum vulgare)	10.9	11.1	14.4	2.0	32.4	0.6	0.9
12	Date (Phoenix dactyliferu)	17.1	35.5	3.1	0	1.1	0.1	6.4
13	Eucalyptus (Eucalyptus globulus)*	9.1	26.2	1.4	2.0	21.5	6.5	2.7
14	Mustard, black (Brassica nigra)	13.2	21.7	8.6	2.7	22.0	1.2	2.5
15	Mustard, common (B. campestris)	9.9	25.3	9.6	1.1	21.7	1.2	2.8
16	Oak (Quercus kelloggii)	11.5	19.1	6.6	2.8	32.5	2.0	2.0
17	Olive (Olea europeae)	10.1	16.7	4.7	1.1	28.3	5.8	1.9
18	Peach (Prunus persica)	8.5	26.5	2.7	1.6	21.8	9.0	2.8
19	Pine, digger (Pinus sabiniana)*	14.1	11.4	2.7	2.2	7.5	3.5	2.6
20	Pine, lodgepole (P. contorta)	7.0	7.0	2.0	3.7	41.2	3.4	1.3
21	Pine, monterey (P. radiata)*	11.2	13.4	1.8	2.4	0.05	11.4	2.4
22	Red-maids (Calandrinia ciliata)	9.1	16.8	5.7	7.1	29.1	2.7	2.7
23	Thistle, milk (Silbum marianum)	15.4	19.9	7.6	1.2	26.4	0.2	1.9
24	Thistle (Centaurea solstitialea)	16.2	21.2	6.6	1.2	21.6	2.1	1.8
25	Walnut (Juglans hindsii)	3.9	23.2	17.6				3.1
26	Willow, black (Salix nigra)	12.3	22.2	4.2	1.4	30.2	0.6	2.6

67. LIGNIFIED CELL WALLS: CHEMICAL COMPOSITION

Values are grams per 100 grams, dry-weight tissue.

	Constituent	Beech (Fagus)[1]		Fir (Abies)[2]		Spruce (Picea)[3]		Pine (Pinus sylvestris)			Poplar[4]			Rye[5]	Wheat[6]
		Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood	Wood Near Branches	Branch Wood	17 yr old	43 yr old		
1	Cellulose	49[7]				49[7]		49	50	51	47	47	44	52	48
2	Mannan					9.1[7]		12	9.8	7.7	7				
3	Galactan					0.3[7]		0.3	0.5	1.1	1.6				
4	Hexosans											16.1	16.7		
5	Pentosans	27[7]				6.7[7]		10	11.1	11.6	13.4	15.9	17.1	30	27
6	Polyuronides					2.0[7]									
7	Lignin	23[7]				28[7]		29	29	29	31	19.3	24.3	15.7	16.2
8	Liposoluble extract					1.8[7]		3.5	5.9	12.1	29	2	2.4	3	4.1
9	Water	97	65	189	45	170	34								
10	Protein	0.13	0.12	0.098	0.091	0.06	0.06								
11	Fat	0.32	0.27	0.07	0.35	0.53	1.25								
12	Starch	0.08	0.07												
13	Hexosan	↑	↑	11.76	8.42	9.21	9.23								
14	Xylan	20.8	20.0	12.54	10.44	13.48	11.40								
15	Methylpentosan	↓	↓	2.02	2.60	1.34	1.52								
16	Lignin	22.9	22.9	28.7	29.6	30.3	30.2								
17	Cellulose	49.3	49.3	40.1	41.8	39.1	40.3								
18	Water-soluble sugars	2.4	1.4	1.66	2.14	1.86	1.61								
19	Resin and wax	0.06	0.14	0.40	1.76	0.63	2.18								
20	Humin			5.79	5.51	5.76	5.80								
21	Ash	0.39	0.33	0.25	0.42	0.24	0.30					0.8	0.7	5.5	6.5
22	K_2O	0.12	0.09	0.05	0.16	0.04	0.04								
23	Na_2O	0.002	0.003												
24	CaO	0.12	0.12	0.11	0.09	0.12	0.13								
25	MgO	0.04	0.03	0.03	0.04	0.05	0.04								
26	MnO	0.004	0.003												
27	Fe_2O_3	0.02	0.03												
28	SiO_2	0.02	0.03												
29	P_2O_5	0.02	0.02	0.02											
30	SO_3	0.03	0.03			0.03	0.03								
31	Cl	0.007	0.005	0.004	0.005	0.001	0.002								

/1/ Fagus sylvatica. /2/ Abies alba. /3/ Picea abies. /4/ Populus canadensis. /5/ Secale cereale. /6/ Triticum eaculentum. /7/ Type of wood unspecified.

68. CORN COLEOPTILE: CHEMICAL COMPOSITION

	Constituent	9 mm[1]		32 mm[1]		55 mm[1]			Constituent	9 mm[1]		32 mm[1]		55 mm[1]	
		mg^2	$g/100g^3$	mg^2	$g/100g^3$	mg^2	$g/100g^3$			mg^2	$g/100g^3$	mg^2	$g/100g^3$	mg^2	$g/100g^3$
	Cell wall								Cell content						
1	Cellulose	0.19	8.3	0.93	13.2	1.62	13.0	4	Water solubles	1.02	44	2.65	40	5.70	46
2	Hemicelluloses	0.23	9.0	0.97	14.5	1.37	11.0	5	Protein	0.51	22.2	1.02	15.2	1.63	13.1
3	Pectin	0.05	2.2	0.27	4.0	0.58	4.7	6	Ash	0.16	6.9	0.30	4.4	0.44	3.6

/1/ Refers to length of corn coleoptile. /2/ mg per coleoptile. /3/ Grams per 100 grams, dry-weight tissue.

69. NECTAR: SUGAR CONTENT

Unless otherwise specified, values are grams of indicated sugar per 100 grams or milliliters nectar.

	Species	Total Sugar mg/flr/24 hr	Total Sugar g/100g[2]		Species	Total Sugar g/100ml	Fructose g/100ml	Glucose g/100ml
1	Alfalfa (Medicago sativa)	0.1	33	23	Basswood (Tilia vulgaris)	21-42	5.4-10	5.3-9.8
2	Apple (Pyrus malus)	0.8	75	24	Blackberry (Rubus fruticosus)	15.6-45	5.2-14.2	5.3-13.5
3	Banana (Musa paradisiaca sapentum)	74	27	25	Borage (Borago officinalis)	22-29	3.8-6.8	4.0-6.9
4	Cherry, sour (Prunus cerasus)	1.2	15	26	Clover (Trifolium pratense)	8.3-30	2.3-8.0	0.7-2.2
5	Cherry, sweet (P. avium)	0.5	21	27	Clover (T. repens)	25-39	9.6-14.2	7.7-12.2
6	Cucumber (Cucumis sativus)	1.0	30	28	Fireweed (Epilobium angustifolium)	18.4-41	7.9-16.3	5.5-11.3
7	Horsechestnut (Aesculus hippocastanum)	1.1[2]	69	29	Ivy (Hedera helix)	10-11.5	2.5-2.6	7.6-8.7
8	Hound's-tongue (Cynoglossum amabile)	0.3	36	30	Lavender (Lavandula spica)	24-32	2.8-4.4	2.0-3.2
9	Jasmine (Jasminum primulinum)	0.3	33	31	Loganberry (Rubus loganobaccus)	17-51	8.3-26	8.3-25
10	Locust (Robinia pseudoacacia)	1.0	55	32	Mint (Pycnanthemum pilosum)	14-26	4.6-9.4	0.2-0.6
11	Milkweed (Asclepias cornutii)	3.1	58	33	Mustard (Brassica alba)	9.3-17.6	4.3-8.3	5.2-9.5
12	Morning glory (Ipomoea purpurea)	8.0	41					
13	Nasturtium (Tropaeolum majus)	1.7	46		Species	Total Sugar g/100g	Sucrose g/100g	Fructose g/100g	Glucose g/100g
14	Nettle (Lamium album)	0.8[2]	42	34	Cotton, acala (Gossypium sp)	28	0.71	14.27	10.36
15	Pear (Pyrus communis)	0.3	16	35	Cotton, pima (G. barbadense)	20	0.35	10.36	9.25
16	Pumpkin (Cucurbita pepo)	28	28	36	Eucalyptus (Eucalyptus globulus)	16.5	5.78	5.47	5.23
17	Rape (Brassica napus)	0.5	47	37	Prune, French (Prunus domestica)	20	1.83	← 18.20 →	
18	Raspberry (Rubus idaeus)	7.6	46	38	Prune, Italian (P. domestica)	9.9	0.76	← 9.10 →	
19	Snapdragon (Antirrhinum majus)	1.5	45	39	Poinsettia (Euphorbia pulcherrima)	48	9.69	17.48	21.01
20	Storax (Syrax officinalis)	1.1	79	40	Orange, navel (Citrus sinensis)	26	12.87	7.46	5.42
21	Sunflower (Helianthus annuus)	0.3	38	41	Orange, Valencia (C. sinensis)	23.4	12.38	6.08	5.06
22	Sweetclover (Melilotus alba)	0.04	36	42	Wax-plant (Hoya carnosa)	41	29	← 11.9 →	

/1/ mg of nectar sugar produced by each flower of the plant specified per 24 hr period. /2/ Value from small number of determinations.

70. PLANT MICROORGANISMS AND RELATED MATERIALS: CHEMICAL COMPOSITION

Values, except those for "Water, Free," are grams per 100 grams dry weight of organism, whole virus complex, or related material. Those for "Water, Free," are grams per 100 grams wet weight, except where otherwise indicated.

	Organism or Related Material	Protein	Carbohydrate[1]	Lipid, Total	Nucleic Acid DNA[2]	Nucleic Acid RNA[3]	Water, Free	Ash	Elements C	H	N	P	S
	Fungi												
1	Alternaria spp								46.0-51.0		4.0		
2	Aspergillus clavatus	22-35	57.6	7.6-16.6					48.8		3.6-5.6		
3	A. nidulans	13-26	54.5	16.8-19.9					49.4		2.1-4.1		
4	A. niger	28.1	69.3	0.3-26			1.5-7.5		41.0-49.4		4.7-7.6	0.1-0.3	0.08-0.13
5	A. oryzae	34-38	61.3	1.8-5.6			8.1		42.1-45.8		5.4-6.1	1.72	0.04
6	A. sydowi	21-35	68.1	5.0-12.0					39.8-52.2		3.3-5.7		
7	Cephalotheclum roseum								52.5				
8	Cladosporium spp								52.5-53.5		2.6		
9	Dematium pullulans								44.1		2.8-4.7		
10	Fusarium javanicum								55.5				
11	Gliocladium spp								53.1		2.4		
12	Helminthosporium gramineum								51.3		3.2-3.7		
13	Mucor stolonifer			7.0			6.9				8.2		
14	Penicillum chrysogenum	15-44	54.0	2.3-7.1					45.4-48.2		2.4-7.0		
15	P. cyaneo-fulvum	22-36	60.5	3.2-8.2									
16	Rhizopus nigricans						6.1-12.2				5.8		
17	Rhodotorula graclis			31.2-49									
18	Saccharomyces cerevisiae	61.3	25.4[4]	4.8			8.5				8.4		
19	Sordaria spp								49.8				
20	Sporotrichum carneolum								51.1				
21	Trichoderma lignorum								49.4		2.6-10.3		
22	Torulopsis lipofera			28.1							5.4	5.2	
23	T. utilis			6.4							7.3-9.2		
24	Ustilago avenae								52.0				
25	Yeast		790-830[5]	7			61-67	8.7			7.5		
26	Yeast cell wall	13	+	8.5			11.2	3.2			2.1	0.3	
	Bacteria												
27	Agrobacterium tumefaciens		1.5	7-8.1			5.0-8.2[6]	6.8-27.8			5.3-10.3	2.0-4.3	0-0.3
28	Azotobacter chroöcoccum						85	4.2	22.4		2.9		
29	Bacillus anthracis						80	7.8			9.2		
30	B. anthracis, spores						85	1.2	52.1	6.8	12.4-16.2		
31	B. mycoides	52.4		0.4			88	5.6			10.3-11.3		
32	B. subtilis	10.1%[7]		4.4			0[8]	10.8			10.1	3.1	
33	B. subtilis, spores	63.7			1.5	4.4	69[8]				11.2	1.8	
34	Brucella abortus	13.3%[7]	1.1-1.5[9]	5-6			4-5[6]	4.8-5.1			13.2-13.4	1.2	0.5
35	Br. melitensis	12.8%[7]	1.8-2.7[9]				3.5-5.1[6]	4.5-5.3			12.7-13	1.3	0.4
36	Br. suis	13.8%[7]	2.6-3.4[9]				1.1-2.2[6]	4.3-5.1			13.7-14	1.4	0.6
37	Corynebact. diphtheriae	9.8%[7]		4.9	1.7	4.8	84		48.9	8.6	9.8-11.2	0.6	1.4
38	Diplococcus pneumoniae[10]	10.4%[7]						5.8[11]	50[11]		9.4		
39	Escherichia coli	72.4	4.0	4.0	5.2	19.1	73	8.6			11.9-13.2	2.7	0.1
40	Klebsiella pneumoniae	8.9%[7]	36.1				86	3.0-7.2	49		8.9		
41	Malleomyces mallei	54.9		39.3			76	5.2	41.8	5.9	12.6-14.0	1.1	1.0
42	Micrococcus pyogenes[12]	54.9		2.8				13.9			13.2	1.8	0.4
43	Mycobact. tuberculosis	53.6		39.0			85.9	9.6	47.4-63	7-9.2	7.3-9.4	0.6-2.7	0.2-1.4
44	Neisseria gonorrheae		5.1-5.3	10-10.3				7.2-8.9			12.4-13.3		7.2-8.9
45	Proteus vulgaris	47.0	14.2	11.5			80	10.9			8.8		
46	Pseudomonas aeruginosa				4.9	4.4	75	9.0			10.3		
47	Salmonella typhimurium	9.6%[7]		4.9			78				9.6		
48	S. typhosa	9.9%[7]					79	5.7			9.9		
49	Serratia marcescens						78	6.9-13.9			10.6		
50	Shigella dysenteriae	74.0[13]		5.4[13]			78	8.3			8.9		
51	Streptococcus pyogenes[14]										13.2-13.7	2.3	
52	Vibrio comma	73.1			2.1	1.6	73	1.3-3.7	50		9.8-12.3		
	Viruses, Rickettsiae and Related Materials												
53	Equine encephalomyelitis[15]	49	4.0	54	0	4.4		2.8	62.2	9.2	7.7	2.2	
54	Influenza A, PR 8	65	4-8[4]	44	0	0.9	52.0	3.3	53.2-55.1	7.9	10.0-10.3	0.9-1.1	
55	Influenza B, Lee	64	13.1(?)	33	0	0.9	34.5		52.7		9.6-10.4	0.7-0.94	
56	Influenza, swine	68	10.0	24	+	?	43.3		51.4		9.0	0.87	
57	Japanese B encephalitis							4.8	54.4	7.5	11.9	1.5	
58	Newcastle disease[16]	67	7.1	27					51.8		9.9	0.85	
59	Rabbit papilloma, Shope	90	6.5	1.5[17]	8.7		58.0	2.5	49.6	7.2	14.5-15.0	0.94	2.2
60	Rous sarcoma							2.0-5.8			15.3		
61	Vaccinia, element. bodies	89	2.8	5.7	5.6	0	5.6[6]	0.72	33.7		15.3	0.57	
62	Alfalfa mosaic	85	9.0			15		3.0	53.8	6.7	16.2	1.4	0.65
63	Cucumber, 3, 4	94	2.3			6		2.3	50.0	7.0	15.4	0.54	0
64	Potato mosaic, latent	92				6			47.8	7.4[18]	14.6-16.1	0.5-0.7	1.1
65	Ribgrass mosaic	94	2.3			6		2.3	50.3	7.0	15.7	0.6	0.64
66	Southern bean mosaic	79				21		5.7	45.6	6.5	17.0	1.9	1.3
67	Tobacco mosaic	94	2.5		0	6		1.5	51.0	7.6	16.6	0.56	0.2
68	Tobacco necrosis	82	6.5			18		5.8-7.0	45.0	6.8	16.3	1.6	1.6
69	Tobacco ringspot	60	18.0		0	40			50.5	7.6	14.6	3.6	0.39
70	Tomato mosaic, mucuba		2.5			6		1.5	50.0	7.0	16.7	0.52	0.2
71	Tomato bushy stunt	83	6.0		0	17		3.0	47.5	7.7[18]	15.8-16.4	1.3-1.5	0.4-0.8
72	Tomato enation		2.5			6		1.0	50.0	7.0	16.7	0.54	0.3
73	Turnip mosaic, yellow	65					35				14.4-15.3	3.4	
74	Bacteriophage, staph.		1.5					13	40.6-41.8	5.3	14.1-14.6	4.6-5.0	
75	Bacteriophage, T_2	51	13.6	2.6(?)	50	0			42.0		13.5	4.8	
76	Rickettsia prowazeki	35	4.1	47	1.5[21]			3.0			12.2	0.93	
77	Chick embryo tissue[22]	41	7.0	35	0	10.6							

/1/ By difference (includes ash varying from 2.5-8.9%), unless otherwise indicated. /2/ Desoxyribomcleic acid. /3/ Ribonucleic acid. /4/ Actual analysis. /5/As jig glucose. /6/ Loss in water. /7/ Percent nitrogen. /8/ Bound water. /9/ Crude C polysaccharide. /10/ Type I. /11/ Type not specified. /12/ Var. aureus. /13/ Paradysenteriae, Flexner. /14/ Mucoid. /15/ Eastern. /16/ California. /17/ Fatty acid. /18/ Range 7.3-7.6. /19/ Range 7.2-8.2. /20/ Range 33.4-40.3. /21/ Range 0.5-2.5. /22/ Normal component.

Values, unless otherwise indicated, are: for protein, grams per 100 grams of protein on a moisture-free, ash-free basis; for fungi and bacteria,

	Substance	Alanine	Arginine	Aspartic Acid	Cystine[1]	Glutamic Acid	Glycine	Histidine	Isoleucine	Leucine
	Animal Proteins									
1	Actin	6.3	6.6	10.9	0.9	14.8	5.2	2.9	7.5	8.2
2	Albumin, egg	7.6	6.0	9.3	2.8	16.5	3.6	2.9	7.0	9.9
3	Albumin, serum, human		6.2	10.4	5.6	17.4	1.6	3.5	1.7	11.0
4	Casein, α-, cow	3.8	4.3	8.4	0.4	22.5	2.3	2.9	6.4	7.9
5	Casein, human	2.0	3.4	4.7	0.6	20.9		2.0	6.3	12.2
6	Fibrin, beef	4.0	7.7	11.9	1.9	13.8	5.2	2.1	5.7	6.7
7	Fibrinogen, human	3.7	7.8	13.1	2.3	14.6	5.6	2.6	4.8	7.1
8	Fibroin, silk	25.8	1.1	2.6	0.0	2.2	43.6	0.4	1.2	0.9
9	Gelatin	10.0	8.0	7.5	0.1	10.8	26.0	0.8	1.3	2.9
10	Globulin, α-, serum[4]		7.7	9.0	1.5	21.6	3.1	2.8	1.7	14.2
11	Globulin, β-, serum[4]		6.8	9.8	3.4	14.5	5.6	2.8	5.0	8.2
12	Globulin, γ-, serum[4]		4.8	8.8	2.4	11.8	4.2	2.5	2.7	9.3
13	Hemoglobin, horse	9.8	3.7	10.6	0.5	8.2	5.6	7.8	1.6	16.6
14	Hemoglobin, human	10.2	3.3	11.0		7.2	4.8	8.4	0.2	15.1
15	Lactoglobulin, γ-	7.1	2.8	11.6	3.5	20.0	1.5	1.7	8.0	15.8
16	Myosin, rabbit	6.9	7.1	11.4	1.0	22.8	2.9	2.3	5.5	10.3
17	Wool	4.0	10.6	7.4	13.6	14.0	6.8	1.1	4.3	8.6
	Enzymes									
18	Pepsin		1.0	16.0	2.1	11.9	6.4	0.8	10.8	10.4
19	Phosphorylase	4.8	11.6	10.4	0.4	13.6	3.9	3.3	6.5	10.5
20	Ribonuclease		5.2	14.2	6.5	13.0	1.3	4.2	3.1	0
	Hormones									
21	Growth hormone, ox		9.0	10.4	2.3	12.9	3.7	2.6	4.1	12.1
22	Insulin	4.5	3.4	6.8	12.5	18.6	4.3	5.3	2.8	13.2
23	Lactogenic hormone, sheep		8.6	11.6	3.1	14.1	4.0	4.5	7.2	12.5
	Plant Proteins									
24	Arachin, peanut	4.0	13.5	4.9	1.4	17.0	3.2	2.4	7.7	8.0
25	Edestin	5.5	16.7	12.0	1.2	20.7	5.1	2.6	4.6	7.4
26	Gliadin	2.1	2.7	1.3	2.6	45.7	0.5	1.9	5.4	6.5
27	Globulin, pumpkin seed		16.3					2.2	4.6	8.0
28	Globulin, wheat bran		13.3					1.9	3.8	6.4
29	Gluten, corn		2.1		1.0	24.5	4.3	1.5	5.1	16.0
30	Gluten, wheat	2.8	3.3	9.6.	1.9	27.0	7.0	1.9	4.2	7.0
31	Phaseolin, kidney bean		6.0					2.2	6.7	10.5
32	Zein	12.3	2.0	6.6	0.9	26.9	0.4	1.7	7.3	23.7
	Fungi[5]									
33	Aspergillus niger		1.0	+		+		0.9	0.9	1.5
34	A. niger, before sporulation		2.6					1.2	1.4	2.6
35	A. niger, after sporulation		1.4					1.5	0.7	1.3
36	A. niger, spores		1.2					0.5	1.0	1.7
37	A. oryzae		+		+			+		
38	A. sydowi		0.6	0.2		0.1		0.1	0.2	1.4
39	Penicillium notatum		1.4					1.7	1.2	2.1
40	Rhizopus nigricans		1.2					1.0	1.0	1.5
41	Rhodotorula rubra		3.7					2.0	2.1	3.3
42	Saccharomyces cerevisiae		2.4					2.7	2.5	3.8
43	Yeast, baker's[6]		5	8	1.2	11		7	3	5
44	Yeast, brewer's[6]		10	7	1.5	12		7	3	5
45	Yeast, commercial		4.3		1.0			2.8	5.9	7.4
	Bacteria[5]									
46	Aerobacter aerogenes[7]		10.4			5.6		3.4		
47	Agrobacter tumefaciens			2.8		1.6				
48	Azotobacter agile[8]		9.5		0.4			0.1		
49	A. vinelandii[8]		8.3-13.2	7.3	0.4	6.8		0.1-7.9		
50	Bacillus brevis[7]		9.9			7.3		2.5		
51	B. subtilis[7]		7.6			5.3		2.5		
52	Corynebacterium diphtheriae[8]		5.3	3.9		3.0		0.6	1.2	1.0
53	Escherichia coli[8]		6.6-7.8		-			1.9-6.4	6.3	7.4
54	E. coli, bacteriophage[9, 10], host[11]	8.4	8.2	9.6		9.6	7.9	3.3	4.6	8.7
55	Lactobacillus arabinosus[8]		3.3			10.5-12.0		1.7-1.9	5.5	5.9-6.2
56	L. casei[8]		3.6			9.7		1.9	6.2-6.7	6.8
57	Micrococcus pyogenes, S[12]		8.9					6.3		
58	M. pyogenes, R[13]		5.4					5.1		
59	Mycobacterium tuberculosis[8]		3.8-13.8		1.3-1.7	5.1		0.9-7.2		
60	Neisseria gonorrheae		4.3-6.0		0.6					
61	Proteus vulgaris[7]		7.7			4.9		4.4		
62	Streptococcus fecalis[7]		5.4			4.4		2.0		
63	Streptomyces griseus		2.9					0.8	1.6	3.8
	Viruses[5]									
64	Influenza A, PR 8	2.5	5.0	7.4		7.7	2.5	1.4	5.2	5.3
65	Papilloma, Shope	3.1	7.0	10.7	6.4[14]	11.4	3.1	1.8	4.1	7.5
66	Polyhedral, silk worm[7]	4.7	18.4	8.1	+	3.7	5.8	1.4	7.6[13]	4[13]
67	Cucumber[4]	6.1	9.3	13.1	-	6.5	1.5	-	4.6	9.4
68	Rib-grass	6.4	9.9	12.6	-	15.5	1.3	0.7	5.9	9.0
69	Tobacco mosaic	5.1	9.8	13.5	-	11.3	1.9	-	6.6	9.3
70	Tomato aucuba[15]	5.1	11.1	13.7		11.5	1.9	-	5.7	9.2
71	Bacteriophage, E. coli[9, 10]	9.4	6.5	12.0		12.0	7.3	<2.6	3.9	6.5

/1/ Values are cystine 1/2, and do not include small quantities of cysteine reported for some proteins. /2/ Total nitrogen accounted for by amino proteins of unknown purity, in contrast with the animal and plant proteins which were mostly highly purified preparations. /6/ Expressed as grams bacterial cell infected with bacterial phage. /12/ Var. aureus, smooth. /13/ Var. aureus, rough. /14/ Cysteine plus cystine. /15/ Isoleucine.

grams per 100 grams dry weight of organism; for viruses, grams per 100 grams of the whole virus complex.

Lysine	Methionine	Phenyl-alanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Nitrogen, Total, %	Nitrogen Recovered[2], %	Hydrolysate, Total[3], %	
						Animal Proteins						
7.6	4.5	4.8	5.1	5.9	7.0	2.0	5.8	4.9	16.7	96	111	1
6.5	5.3	7.2	3.8	8.2	4.0	1.2	4.1	8.8	15.8	97	115	2
12.3	1.3	7.8	5.1	3.7	5.0	0.2	4.7	7.7	16.0			3
8.9	2.5	4.6	7.5	6.3	4.9	1.6	8.1	6.3		102		4
5.5	2.2	5.8	8.9	5.4	4.5	1.5	5.4	5.0		79		5
9.0	2.2	7.6	5.3	15.3	9.9	3.6	5.6	5.6	16.8	101	123	6
9.2	2.5	4.6	5.7	6.9	6.2	3.3	5.4	4.1				7
0.8	0.1	1.6	1.0	13.9	1.3	0.4	10.8	3.6	10.0	89	111	8
4.1	0.9	2.6	16.5	3.4	2.2	0.0	0.4	2.3	17.6	95	123	9
8.9	1.4	4.6	4.7	5.0	4.9	1.9	4.5	5.2				10
6.6	1.7	4.7	7.1	7.1	6.1	2.0	6.0	7.0	15.2			11
8.1	1.1	4.6	8.1	11.4	8.4	2.9	6.8	9.7	16.0			12
8.6	1.0	6.5	8.5	5.8	4.4	1.2	2.9	9.0	16.8	97	112	13
9.6	1.4	7.6	4.4	5.0	5.8	1.5	3.0	10.6	16.9			14
11.3	3.2	4.8	5.0	4.4	5.5	1.9	3.7	5.8	15.5	96	118	15
12.4	3.3	4.5	2.5	4.3	4.9	0.8	3.2	4.9	16.7	98	111	16
3.3	0.7	4.0	8.0	9.8	6.5	1.5	5.5	5.4	16.2	88	115	17
						Enzymes						
1.5	1.7	6.4	5.0	12.2	9.6	2.4	8.5	7.1	15.4	86	113	18
7.2	2.7	6.2	4.7	3.4	4.4	2.0	5.9	7.3	16.5			19
10.4	4.5	3.6	3.6	12.0	9.0	0	7.9	7.3		99		20
						Hormones						
7.2	2.8	7.9			8.9	0.8	4.3	3.9		88		21
2.4	0.0	8.3	2.5	5.2	2.1	0.0	13.4	7.8	15.7	90	110	22
5.3	3.6	4.1	6.2	6.5	4.8	1.2	4.7	5.9	15.9			23
						Plant Proteins						
3.5	0.7	6.4	6.0	5.3	2.7	0.7	5.9	4.5	18.3	72	98	24
3.2	2.4	5.9	4.3	6.1	3.9	1.5	4.3	5.7	18.6	102	113	25
0.8	1.7	6.1	13.4	4.9	2.1	0.6	3.2	2.7	17.7	91	105	26
2.8		7.2			2.6			6.5	16.3			27
4.2	1.0	4.2			3.5	0.9		6.6	13.3			28
1.2	2.5	4.6			4.0	0.3	3.8	5.7	10.9	83	82	29
1.7	1.5	4.1	8.0	4.0	2.5	1.2	1.3	4.1	13.5	70	94	30
7.2	1.1	8.0			4.2	0.5		6.0	16			31
0.0	2.2	6.2	10.5	7.7	2.5	0.1	5.3	3.5	16.0	99	120	32
						Fungi[5]						
1.0	0.2	0.8			1.1	0.3	0.3	1.1				33
2.7	0.5	1.5			1.7	0.5		1.8				34
1.2	0.2	0.8			0.9	0.3		0.9				35
1.3	0.2	1.0			1.3	0.3		1.3				36
+						+	+					37
0.8			0.5	1.8	0.4	0.04	0.4	0.1				38
1.5	0.4	1.2			1.4	0.5		1.5				39
1.6	0.3	0.8			1.0	0.2		1.1				40
3.0	0.5	1.7			1.8	0.4		2.5				41
3.1	0.6	2.1			2.4	0.6		2.8				42
8	0.8	3	3	4	4	-	3	7				43
8	0.8	1	3	3	6	-	2	7				44
7.5	2.7	4.1			5.5	1.3	3.6	5.0				45
						Bacteria[4]						
6.8							1.4					46
												47
5.8						0.5	2.1					48
2.5-4.1						0.2	2.5					49
7.9							2.2					50
7.5							1.5					51
4.1			3.8			+	3.0	3.9				52
4.8-10.5						0.6-1.9	1.8	6.1				53
8.3	2.9	4.8	3.0	4.9	5.3	1.3	4.3	5.0				54
5.2-5.9	1.1	2.8			3.8	0.5		5.2-5.4				55
7.7	1.1	3.5			4.7	0.4-0.6		5.8				56
9.9												57
												58
1.3-7.7		13.7	4.0			1.7-2.7	1.3-2.1	16.3				59
				2.4-3.0	2.9-3.3	1.1	2.3					60
6.4							2.1					61
7.6							0.8					62
2.2	0.6	1.6			2.4	0.7	3.5					63
						Viruses[5]						
3.6	2.3	3.7	2.6	2.2	3.7	1.1	3.1	3.4				64
7.0	2.1	4.6	5.5	4.0	5.1	1.0	5.8	5.4				65
3.0	1.8	+[15]	2.3	6.7	6.8	?	2.4	2.4				66
2.4	-	9.8	5.7	9.4	7.0	0.5	3.7	8.9				67
1.5	2.2	5.4	5.5	5.7	8.2	1.4	6.8	6.2				68
1.5	-	8.4	5.8	7.2	9.9	2.1	3.8	9.2				69
1.4	-	8.3	5.8	7.0	10.4	2.1	3.7	8.8				70
8.5	<1.3	4.2	5.0	4.8	7.0		3.7	6.5				71

acids. /3/ A value greater than 100 is the result of water addition during hydrolysis. /4/ Human. /5/ These analyses were made on mixtures of amino acid N/100g of whole yeast. /7/ As % of total N. /8/ As % of protein. /9/ T_4 phage. /10/ As % of total amino acids. /11/ Represents the plus leucine plus phenylalanine. /16/ Strain green aucuba.

72. CHROMOSOME NUMBERS: ANIMALS

Phyla are separated by solid lines; other major systematic groupings are separated by broken lines. Changes in alphabetical sequence of sections between lines indicated transitions from one group to another within a class. s = spermatogonium; o = oogonium; m = somatic cell. Data adapted and revised by S. Makino from his "Atlas of Chromosome Numbers in Animals." Superscripts after species refer to sex types in footnotes.

	Species	Chromosome Number (2n)
1	Rhopalura ophiocomae	6m
2	Sycon ciliatum	26 m
3	Hydra circumcincta	30 m
4	H. vulgaris attenuata	32 s, o, m
5	Pelmatohydra obligactis	30 m
6	Monlesia sapensa	12–14(?) m
7	Fasciola hepatica	12 o, m
8	Pyrorchis acanthus	22 s
9	Schistosoma japonicum	16 s, o
10	Polystomum integerrimum	20 m
11	Aphanostoma diversicolor	20-30
12	Stenostomum grandi	20-40
13	Mesostoma ehrenbergii	10 m
14	Microstomum hispirata	16 s
15	Dalyellia spp	8 s
16	Amphibolella virginiana	4 s
17	Castrada sp	6, 8 s
18	Polycystis goetlei	16 s
19	Plagiostomum stellatum	10 s
20	Curtisia forensanti	12 s, o
21	Thysanozoon brocchi	18 s, m
22	Micrura caeca	32 m
23	Asplanchna intermedia	24 s, o m
24	Dinophilus spatira	20 m
25	Allolobophora chlorotica	32 m
26	Dendrobaena subrubicunda	68 m
27	Eisenniella tetraedra	72 m
28	Lasice conchylega	6 m
29	Ophryotrocha gracilis	10 s, o, m
30	Sabellaria spinulosa	8 s, m
31	Glossasiphonia complanata	26 s
32	Protoctepsis tesselata	16 m
33	Phascolosoma gouldii	20 m
34	Sagitta spp	12 s, m
35	Mactra sp	24 m
36	Compsoma rufum	12 o
37	Pterotrachea mutica	32 m
38	Tulotoma magnifica	24
39	Viviparus contectoides	26
40	Limacina retroversa	24 s, m
41	Montagua gouldii	32 m
42	Lymnaea japonica	36 s
43	Arion empiricorum	32 m
44	Euhadra awaensis	58 s
45	Cepaea hortensis	48 s
46	Helicigona arbustorum	48 s
47	Helix aspersa	54 s
48	H. pomatia univalens	24 s
49	Limax cinereo-niger	16 s
50	Incillaria fruhstorferi	48 s
51	Polygyra appressa	60–62 s
52	Stenotrema hirsutum	58 s
53	Succinea horticola	34 s
54	S. ovalis	40 s
55	Echinorhynchus gigas	8 m
56	Ascaris lumbricoides[1]	43–48 s
57	A. megalocephala bivalens	4 s, o, m
58	A. m. univalens	2 s, o, m
59	Splrina parasitalrs	14 s
60	Heterakis sp[2]	9 s
61	Rhabditis monohysters	20 o, m
62	Ophiostomum mucronatum	12 m
63	Strongylus paradoxus[2]	11 s
64	Gordius spp	4 s, o, m
65	Pedicellina americana	22 s, o, m
66	Asterias amurensis	30 s
67	Strongylocentrotus lividus	36 m
68	Toxopneustes variegatus	36 m
69	Henricia nipponica	54 s
70	Artemia salina	42 s (4n,84s)
71	Daphnia pulex	20 m
72	Heterocypris incongruens	20 o, m
73	Calanus finmarchicus	34 s, o
74	Diaptomus castor	34 m
75	Heterocope weismanni	32 s
76	Copilia denticornis	16 s
77	Cyclops fuscus	14 m
78	C. gracilis	6 m
79	C. insignis	22 m
80	C. viridis	12 s, o, m
81	Hersilia apodiformis	24 s, o, m
82	Mytilicola intestinalis	22 o, m
83	Sculpellum scalpellum	32 s, o

	Species	Chromosome Number (2n)
84	Armadillidium opacum	54 s
85	Ligia exotica	72 s
86	Porcellio scaber	56 s
87	Prosaellus meridianus	16 s
88	Trichoniscus elisabethae	16 s (3n, 24s)
89	Gryllotalpa africana	52 s
90	Cambaroides japonicus	196 s
91	Macrocheira kaempferi	106 s
92	Eupagurus ochotensis	254 s
93	Telphusa fluviatilis	78 s
94	Pediculogaster graminum	6 m (parth., 3n)
95	Agalena opulenta[3]	44 s
96	Aranea dumetorum[3]	14 s
97	Tetragnatha japonica[3]	24 s
98	Clubiona japonicola[3]	20 s
99	Drapetisca socialis[3]	24 s
100	Heptathela kimurai[3]	80 s
101	Schizocosa crassipes[3]	22 s
102	Oxyopes ramosus[3]	21 s
103	Philodromus roseus[3]	28 s
104	Ixlus elongatus[3]	28 s
105	Heteropod. venatoria[4]	41 s
106	Ariamnes cylindrogaster[3]	22 s
107	Xysticus viaticus[2]	23
108	Cladiologa pedestris	16 s
109	Buthus martensii	24 s
110	Tityus bahiensis	20 s
111	Trichopleura tricarinata	26 s
112	Forcopalpus armillatus	20 s
113	Macrobiotus lucztotn	10 m
114	Thelyonemella hilgendorfi[5]	36 s
115	Oliocryptops sexspinosus[5]	15 s, 14 o
116	Anurida maritima	8 o
117	Lepisma domestica	34 s
118	Acrida turrita[4]	23 s
119	Atractomorpha ambigur[2]	19 s
120	Chorthippus (Stenobothrus) lineatus[2]	17 s
121	Chorthophaga viridifasciata[2]	23 s
122	Chrysochraon japonicus[2]	23 s
123	Circotettix verruculatus[2]	21 s
124	Hesperotettix pratensis[2]	22 s
125	Dissosteira sp[2]	23 s
126	Gomphocerus rufus[2]	17 s
127	Locusta migratoria[2]	23 s
128	Mecostethus lineatus[2]	23 s
129	Melanoplus dawsonii[2]	23 s
130	Mermiria bivittata[2]	22 s, o, m
131	Miramella alpicsamra[2]	21 s
132	Oxya intricata[2]	23 s
133	Paratylotropidia brunneri[2]	19 s, 20 m
134	Philocleon anomalus[2]	12 s
135	Podisma mikado[2]	21 s
136	Romalea microptera[2]	23 s
137	Schistocerca alutacea[2]	23 s
138	Stauroderus bicolor[2]	17 s
139	Syrbula sp[2]	23 s
140	Tetrix subulata monticulisa[2]	23 s
141	Traulia oreata[2]	23 s
142	Trimerotropis sp[2]	23 s
143	Zuborskya glacialis[2]	21 s
144	Blatta orientalis[2]	47 s
145	Periplaneta australasiae[2]	27 s
146	Acheta campestris[4]	29 s
147	Apithes agiitator[2]	13 s
148	Endocoa cavernicola[2]	23 s
149	Gryllus assimilis[2]	29 s
150	Lebinthus sp[2]	11 s
151	Liphoglena kawatakai[2]	19 s
152	Madasumma hibinonis[2]	15 s
153	Oecanthus longicaud[5]	20 s
154	Scapiscus sp[2]	17 s
155	Galloisiana nipponensis[5]	30 s
156	Grylloialpa africana[2]	23 s
157	Amblycorypha oblongifolia[2]	33 s
158	Conocephalus sp[2]	33 s
159	Ephippigera vitium[2]	29 s
160	Hexacentrus mundus[2]	31 s
161	Isotima japonica[2]	27 s
162	Kuwayamaea sapporensis[2]	27 s
163	Mecopoda elongata[2]	27 s
164	Odontura maraccana[2]	27 s
165	Sega pedo	680 m
166	Scudoria sp[2]	31 s

	Species	Chromosome Number (2n)
167	Xiphidion gladiatum[2]	33 s
168	X. maculatum[2]	21 s
169	Mantis religiosa[2]	27 s
170	Creobroter lseviculis[2]	27 s
171	Iris oratoria[2]	25 s
172	Toxoramtis sinensis[2]	27 s
173	Bostra sp[2]	35 s
174	Isagoras sp[2]	47 s
175	Oncotophasma sp[2]	41 s
176	Pseudophasma menius[2]	23 s
177	Diestrammena marmorata[2]	27 s
178	Tridactylus japonicus[2]	13 s
179	Labidura riparia[2]	14 s
180	Hogeria grammatica[2]	26 s
181	Perla maxima[3]	19 s
182	Perlodes microcephala[4]	27 s
183	Zoorthoptera neguifolia[2]	26 m
184	Cerastipsocus venosus[2]	17 s
185	Liposcus baculus	16 s
186	Liposcus columbae	16 s, o
187	Ephemera danica	11 s
188	Nesahia cretulae[2]	25 s, 25 o
189	Anax junius[2]	27 s, 28 o
190	Ictinus rapax[2]	23 s
191	Lasodes trivialis[2]	25 s
192	Orthetrum sabina[2]	25 s
193	Sympetrum pedemontanum[2]	25 s
194	Trithemis pallidinervis[2]	25 s
195	Ceriagrion rubiae[2]	27 s
196	Lestes sponsa[2]	25 s
197	Phyllaplis cowani	9 s, 8 o
198	Aphis oenothera	10 s, m
199	A. salicetti[2]	5 s, 6 m
200	Cinara pectinata	20 ♀m
201	Euceraphis betulae	8 s, o, m
202	Hyalopterus pruni	9 s
203	Macrosiphum piai[4]	7 s, 8 9m
204	Melahaxanthus salicicola	6 s, 9m
205	Myzus linderae[2]	11 s, 12 o
206	Phyllorera fallax[3]	10 s, o, 9m
207	Tetraneura ulmi[2]	13 s, 14 o
208	Aphrophora costalis[5]	30 s
209	Clastoptera obtusa[2]	15 s
210	Dactylopius sp	10 ♀m, ♂s
211	Icerya purchasi	4 s, o, m
212	Gossyparia spuria	28 s, ♂m, ♀m
213	Lecanium hesperidum	14 m
214	Llaveia banvari[2]	5 s, 6 o
215	Nautococcus schraderae[2]	5 ♂m, 6 ♀m
216	Pseudococcus acericola	12 s, o
217	Amphicerus bicaudatus	25 s
218	Phlepsius irroratus[2]	15 s
219	Campylencha curvata[2]	19 s
220	Deltocephalus bicutus[5]	20 s, o
221	Entilia sinuata[2]	21 s
222	Vanduzea arcuata[4]	17 s
223	Halictus cephalicus[2]	24 s
224	Adelphocoris lineolatus[2]	17 s
225	Notostira erratica[2]	17 s
226	Urolabida stsderi	31 s
227	Alydus calcaratus[2]	13 s
228	Anasa tristis[2]	21 s
229	Archimerus alternatus[2]	15 s
230	Camptopus lateralis[2]	13 s
231	Metapodius femoratus[5]	22 s, o
232	Diactor bilineatus[2]	21 s
233	Syromastes marginatus[5]	22 s, o
234	Thyreocoris pictus[2]	21 s
235	Protenor belfragei[2]	13 s, 14 o
236	Callicoriax caledonica[5]	24 s
237	Coptosoma bonadorffi[5]	26 s
238	Corixa punctata[5]	24 s
239	Leptocoris haemotoloma[2]	13 s
240	Dysodius lunatus[2]	31 s
241	Gerris lateralis[2]	21 s
242	Lygaeus turcius[5]	14 s, o
243	Hygotrechus sp[2]	21 s
244	Aphanus japonicus[5]	17 s
245	Eremocoris erraticus[5]	20 s
246	Geocoris japonicus[5]	20 s, o
247	Macrodema microptera[5]	18 o
248	Nysius jacobea[5]	14 s, o
249	Oncopeltus fasciatus[5]	16 s, o

/1/ X1–Xs♂. /2/ X–O♂. /3/ X1X2–O♂. /4/ 3X–O♂. /5/ X–Y♂. /6/ 4X–5Y♂. /7/ X1X2–Y♂. /8/ 4X–Y♂.

72. CHROMOSOME NUMBERS: ANIMALS (Concluded)

Phyla are separated by solid lines; other major systematic groupings are separated by broken lines. Changes in alphabetical sequence of sections between lines indicated transitions from one group to another within a class. s = spermatogonium; o = oogonium; m = somatic cell. Data adapted and revised by S. Makino from his "Atlas of Chromosome Numbers in Animals." Superscripts after species refer to sex types in footnotes.

	Species	Chromosome Number (2n)
250	Rhyparochromus chiragra[5]	14 s
251	Stigonocoria rusticus[5]	18 o
252	Mesovelia furcata[5]	35 s
253	Neocoria cimicoides[2]	51 s
254	Ranatra linearis[9]	43 s
255	Notonecta undulata[5]	26 s
256	Aelia acuminata[5]	14 s
257	Banasa calva[5]	26 s,o
258	Coptosoma punctissimum[5]	12 s
259	Dinidor rufocinctus[10]	21 s, 22 o
260	Dolycoris baccarum[5]	14 o
261	Eurydema senens[5]	16 s
262	Euschistus fissilis[5]	14 s,o
263	Graphosoma rubrolinestum[5]	14 s
264	Halyomorpha picus[5]	14 s
265	Megymenum gracilicorne[5]	20 s
266	Nezara hilaris[5]	14 s,o
267	Palomena angulosa[5]	16 s,o
268	Pentatoma japingrica[5]	14 s
269	Rhytidolomia sancta[5]	14 o
270	Thyanta accesia[10]	27 s, 28 o
271	Largus cinctus[2]	11 s, 12 o
272	Pyrrochoris apterus[2]	23 s, 24 o
273	Poliedrus armatissimus[5]	12 s
274	Velious nodipes[11]	28 s, 30 o
275	Velia currens[5]	25 s
276	Rhaphidia handschini[3]	25 s
277	Glyptobasis dentifera[2]	22 s
278	Chrysopa aspera[5]	12 s,o
279	C. flava[5]	14 s
280	C. perla[5]	12 s,o
281	C. vulgaris	12 s,o, 9m
282	Semidalis alba	18 o
283	Hemerobius stigma[5]	14 s
284	Myrmeco eo europaeus[5]	14 s,o
285	Palpares pardus asanai[5]	26 s
286	Panorpa japonica[2, 12]	46 o
287	Bittacopsyche grisei[2]pinnis[13]	12 s, 25 9m
288	Chaetopteryx villosa	60 s
289	Halesus tesselatus	42 s
290	Limnophilus affinis	22 s
291	Phryganistoba fallginosa[14]	56 s, 58 o
292	Abraxas grossulariata	26 s,o
293	Biston hirtaria	28 s,o
294	Dendrolimus jezoensis	60 s
295	Bombyx mori	56 s
296	Lymantria dispar	62 s,o
297	L. japonica	62 s,o
298	Orgyia thyellina	22 s
299	Dicranura erminea	56 s
300	D. vimula fennica	42 m
301	D. vimula delavoiei	62 m
302	Pygaera curtula	48 m
303	P. pigra	46 s,m
304	Papilio podalirius	54-58 s
305	P. rutulus	28 s
306	Pieris brassicae	30 s,o
307	P. napi	50 s
308	Fumea casta	62 s, 61 o
309	Chiro simplex	58 s
310	Tischeria emptiticella	28 s
311	Philosamia cynthia	26 s,o, 9m
312	P. cynthia walkeri	26 s
313	P. cynthia pryeri	28 s
314	Teles polyphemus	60 s
315	Deilephila euphorbiae	28 s
316	Solenobia alpicolella	60-62
317	S. triquetrella	62 m
318	Talaeporia tubulosa	60 ♂m, 59♀m
319	Tischeria angusticolella	42 s,o
320	Anthia sexguttata[2]	35 s
321	Dytiscus circumcinctus[5]	38 s
322	Bruchus quadrimaculatus[2]	20 s, 20 m
323	Agrilus anxius[5]	22 s,o
324	Julodis whithilli[2]	24 s
325	Sternocera laevigata[2]	26 s
326	Pterolophia caudata[5]	20 s
327	Agelastica caerulea[5]	24 s
328	Chrysomela exanthematica[2]	23 s
329	Coptocyclа clavata[5]	18 s
330	Luperoides praeusta[2]	32 s,o
331	Melasoma populi[5]	32 s
332	Calvia 14-guttata[5]	20 s
333	Coccinella bruchii[5]	18 s
334	Epilachna pustulosa[5]	20 s
335	Harmonia axyridis[5]	16 s
336	Synercha grandis[5]	20 s,o
337	Acanthoscelides obtectus	20 ♀m
338	Otiorhynchus arcticus	22 s
339	O. gemmatus	33 ♀m (3n)
340	O. scaber	44 ♀m (4n)
341	Polydrosus mollis	22 o
342	Hydrotaea scutellata[5]	10 s
343	Pasilidoremus inclinatus[2]	19 s
344	Melee spp[5]	20 s
345	Anomala rufocuprea[5]	18 s
346	Popillia japonica[5]	18 s
347	Listrotrophus cingulatus[5]	26 s
348	Blaps lusitanica[15]	19 s, 20 o
349	Bisperis bolet[5]	14 s
350	Tenebrio molitor[5]	20 s,o
351	Acrotachinus wheeleri	16 s,o,m
352	Apis mellifica	16 s,o
353	Habrobracon pectinophorae	20 s,o
354	Trigonaspis megaptera	10 s
355	Diprion polystomum	6 s, 12 9m
356	Melitobia chalybii	5 ♂m, 10 ♀m
357	Lasius flava	24 ♀m
358	Aenoplex armithii	13 s, 26 o
359	Peromalus pupurum	5 ♂m, 10 ♀m
360	Thrinax maculа	7 s, 14 o
361	Trichogramma chilonis	5 s, 10 o
362	Polistes fadwiga	9 s, 18 o
363	P. snelleni	13 s, 26 o
364	Fucellia marina	12 m
365	Aulius lecythus[5]	14 s
366	Bibo hortulanus[5]	10 m
367	Calliphora erythrocephala[5]	12 s,o,m
368	Miastor americana	48 s,o, 12 9m
369	Lasioptera asterspinosae	8 ♂m, 6♂m,
370	Chironomus spp	8 s, 150♀s,o
371	Scatophaga pallida[5]	12 s,o
372	Aedes spp[5]	6 s,o
373	Anopheles punctipennis[5]	6 s,o
374	Culex pipiens[5]	6 s,o,m
375	Drosophila melanogaster[5]	8 s,o
376	D. willistoni[5]	6 s,m
377	D. melanica[5]	10 s,o, 6m
378	D. aldrichi[5]	12 o
379	D. virilis[5]	12 s,o,m
380	D. pseudoobscura[5]	10 s,m
381	D. ananassae[5]	8 s,o,m
382	D. obscura[5]	10 s,o, 6m
383	Scatophila unicornis[5]	13 ♂m, 14 9m
384	Melophagus ovinus[5]	18 s
385	Musca domestica[5]	8 s
386	Dicranomyia trinotata	6 s
387	Liponeura cinerascens[5]	10 s
388	Musca domestica[5]	12 s,o
389	Brachypera radiata[5]	12 m
390	Fungivora blanda[5]	8 o, 9m
391	Hypomoia forestrilla[5]	8 m
392	Camptoneura picta	12 s
393	Piophila casei	12
394	Aphiochaeta sp	6 m
395	Physegenua vittata	12 s
396	Sarcophaga sp[5]	12 m
397	Sciara coriaria	8 m
398	Simulium sp[5]	6 m
399	Plectieus trivittatus[5]	16 s
400	Eristalis bastardi[5]	12 s
401	Phorocera hamata[5]	12 ♂m
402	Chaetopsis hilvifrons	8 s
403	Ctenocephalus canis[5]	14 ♂m
404	Leptopsylla musculi[5]	22 s
405	Ciona intestinalis	18 m
406	Branchiostoma japonica[5]	52 s
407	Bdellostoma burgeri	48(?)s
408	Protopterus aniscieus	34 s
409	Raja macrorhynchus	24 s
410	Squalus suckleyi	62 s
411	Betta splendens	42 s
412	Misgurnus angullicaudatus	52 s
413	Acheilognathus lanceolatus	50 s
414	Carassius auratus	94 s
415	Cyprinus carpio	104 s
416	Lebistes reticulatus	48 s
417	Mollienisia sphenops	46 s
418	Platypoecilus maculatus	48 s
419	Xiphophorus helleri	48 s
420	Oncorhynchus keta	74 s
421	Oamerus eperlanus	58 m
422	Salmo carpio	96 s
423	Thymallus thymallus	102 m
424	Ichthyophis glutinosus	42 s, o m
425	Hynobius nebulosus	56 s
426	Amblystoma mexicanum	28 s
427	Salamandra salamandra	24 s
428	Triturus cristatus	24 s
429	Cryptobranchus alleghenienis	62 s
430	Bufo arenarum	22 s
431	B. calamita	22 s
432	B. viridis	22 s, o
433	Alytes obstetricans	36 s
434	Bombina orientalis	24 s
435	Hyla arborea	24 s
436	Pelobates fuscus	26 s
437	Xenopus laevis	36 s
438	Rana japonica	26 s
439	R. pipiens	26 s
440	R. temporaria	26 s,m
441	Rhacophorus schlegelii	26 s
442	Alligator mississippiensis	32 s
443	Chelonia japonica[12]	56 s, 55 o
444	Emys orbicularia	50 s
445	Calotes versicolor[13]	34 s, 33 o
446	Agnis fragilis	36 s,o
447	Chamaelon vulgaris	24 s,o
448	Eublepharis variegatus	32 s
449	Gymnodactylus millisi	38 s
450	Heloderma suspectum	38 s
451	Anolis carolinensis	34 s
452	Sceloporus spinosus	22 s
453	Lacerta viridis	38 s
454	Takydromus tachydromoides	38 s
455	Lacerta vivipara[13]	36 s, 35 o
456	Sciocis officinalis	32 s
457	Amelva surinamensis	50 s
458	Naja naja stra	38 s
459	Ancistrodon acutus	36 s
460	Vipera aspis	42 s
461	Pica pica serica[13]	82 s, 81 o
462	Cuculus canorus	72 s
463	Ciconia ciconia	84 s
464	Egretta garzetta	76 s
465	Aix sponsa	80 s
466	Anas platyrhyncha[13]	80 s, 70 o
467	Cygnus cygnus	80 s
468	Columba livia domestica[13]	80 s, 79 o
469	Bambusicola thoracica	78 s
470	Gallus gallus domesticus[13]	78 s, 77 o
471	Meleagris gallopavo[13]	82 s, 81 o
472	Numida meleagris[13]	82 s, 75 o
473	Phasianus colchicus karpowi[13]	82 s, 81 o
474	Syrnaticus soemmerringii	82 s
475	Didelphys virginiana	22 s, m
476	Myotis myotis[5]	44 s
477	Erinaceus europaeus[5]	48 s
478	Talpa europaea[5]	34 s
479	Lepus cuniculus[5]	44 s
480	Cavia cobaya[5]	64 s
481	Mystator coypus[5]	42 s
482	Mesocricetus auratus[5]	44 s
483	Apodemus agrarius[5]	48 s
484	Micromys minutus[5]	68 s
485	Peromyscus maniculatus[5]	48 s
486	Mus musculus[5]	40 s
487	Rattus norvegicus[5]	42 s
488	Cynomys ludovicianus[5]	52 s
489	Sciurus vulgaris[5]	40 s
490	Canis familiaris[5]	78 s
491	Felis catus[5]	38 s
492	Phocoenoides dalli[5]	44 s
493	Bos taurus[5]	60 s
494	Ovis aries[5]	54 s
495	Sus scrofa	40 s
496	Equus caballus[5]	66 s
497	E. asinus[5]	66 s
498	♂Mule[16]	66 s
499	Macaca mulatta[5]	48 s,m
500	Homo sapiens	48 s,o

[2] X-O♂. [5] X-Y♂. [9] sX-O♂. [10] 2X-Y♂. [11] 3X-Y♂. [12] X-X♀. [13] X-O♂. [14] Z-2W♀. [15] 2XX-Y♂.

73. CHROMOSOME NUMBERS: GYMNOSPERMS AND ANGIOSPERMS

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants," G. Allen and Unwin, Ltd., London, 1945.

	Species	Number
	Gymnospermae	
	Cycadaceae	
1	Zamia (Zamia floridana)	16
	Ginkgoaceae	
2	Ginkgo (Ginkgo biloba)	24
	Taxaceae	
3	Yew (Taxus baccata, T. cuspidata)	24
4	Yew (T. canadensis)	24+f
	Pinaceae	
5	Arborvitae (Thuja orientalis)	22
6	Cedar (Cedrus libani)	24
7	Douglas-fir (Pseudotsuga menziesii)	26
8	Fir (Abies balsamea, A. cephalonica)	24
9	Fir (A.concolor, A.normanniana)	24
10	Hemlock (Tsuga canadensis)	24
11	Hemlock (T. carolinisana)	24
12	Juniper (Juniperus chinensis)	44
13	Juniper (J. communis, J. rigida)	22
14	Larch (Lardix decidua)	24
15	Pine (Pinus spp)[1]	24
16	Redcedar (Juniperus virginiana)	22
17	Redcedar (Thuja plicata)	22
18	Redwood (Sequoia gigunteum)	22
19	Redwood (S. sempervirens)	44
20	Spruce (Picea spp)[2]	24
21	White-cedar (Thuja occidentalis)	22
	Angiospermae: Monocotyledoneae	
	Najadaceae	
22	Eelgrass (Zostera marina, Z. nana)	12
	Alismataceae	
23	Alisma (Sagittariamontevidensis)	20
24	Plantian (Alisma plantago-aquatica)	10
	Hydrocharitaceae	
25	Elodea (Elodea canadensis)	24
26	Elodea (E. densa)	48
27	Vallisneria (Vallisneria gigantea)	40
28	Vallisneria (V. spiralis)	20
	Gramineae	
29	Barley (Hordeum distichum)	14
30	Barley (H. jubatum)	28
31	Barley (H. nodosum)	42
32	Barley (H. vulgare)	14
33	Bluegrass (Poa compressa)	35,42,45, 49,56
34	Bluegrass (P. pratensis)	28-124
35	Corn (Zea mays)	20
36	Crabgrass (Digitaria sanguinalis)	36
37	Dallis grass (Paspalum dilatatum)	40
38	Fescue (Festuca elatior)	14,28,42, 70
39	Gammagrass (Tripsacum dactyloides)	36, 72
40	Johnsongrass (Sorghum halepense)	40
41	Oat (Avena barbata)	28,42
42	Oat (A. fatua, A. sativa)	42
43	Oat (A. strigosa)	14
44	Quackgrass (Agropyron repens)	28, 42
45	Redtop (Agrostis alba)	28, 42
46	Rice (Oryza sativa)	24
47	Rye (Secale cereale)	14
48	Ryegrass (Lolium multiflorum)	14
49	Ryegrass (L. perenne)	14
50	Teosinte (Euchlaena mexicana)	20
51	Timothy (Phleum pratense)	14, 42
52	Wheat (Triticum aestivium)	42
53	Wheat (T. durum)	28
54	Wheatgrass (Agropyron cristatum)	14,28,42
	Cyperaceae	
55	Sedge (Carex hirta)	112
56	Sedge (C. panicea)	52
	Palmae	
57	Coconut (Cocos nucifera)	32
58	Date (Phoenix dactylifera)	36
59	Palmetto (Sabal palmetto)	36

	Species	Number
	Angiospermae: Monocotyledoneae (concluded)	
	Bromeliaceae	
60	Pineapple (Ananas sativus)	50,75,100
61	Spanish moss (Tillandsia usneoides)	32
	Commelinaceae	
62	Rhoea (Rhoea discolor)	12
63	Spiderwort (Tradescantia virginiana)	24+0-6f
64	Wandering-jew (T. fluminensis)	60
	Pontederiaceae	
65	Water-hyacinth (Eichhornia crssipes)	32
	Juncaceae	
66	Rush (Juncus effusus)	40
	Liliaceae	
67	Asparagus (Asparagus officinalis)	20
68	Autumn crocus (Colchicum autumnale)	38
69	Bluebell (Scilla non-scripta)	16
70	Garlic (Allium sativum)	16
71	Grape-hyacinth (Muscari racemosum)	54
72	Helleboro (Venatrum nigrum)	64
73	Hyacinth (Hyacinth orientalis)	16,19-30
74	Lily (Lilium spp)[3]	24
75	Lily, day (Hemerocallis flava)	22
76	Onion (Allium cepa)	16
77	Trillium (Trillium grandiflorum)	10
78	Tulip (Tulipa gesneriana)	24, 36
	Amaryllidaceae	
79	Beladonna (Amaryllis belladonna)	22
80	Century plant (Agave americana)	60, 120, 180
81	Jonquil (Narcissus jonquilla)	14, 28
82	Narcissus (N. poeticus)	14,21,28
83	Narcissus (N. pseudonarcissus)	14,15,20, 22,28,30
84	Yucca (Yucca spp)	60
	Iridaceae	
85	Crocus (Crocus versicolor)	26
86	Gladiolus (Gladiolus spp)	30
87	Iris (Iris orientalis)	14
88	Iris (I. versicolor)	72,84,105
	Musaceae	
89	Banana (Musa paradisiaca ssp.)	22, 33
90	Plantain (M. paradisiaca)	44, 55, 77, 88
	Zingiberaceae	
	Ginger (Zingiber officinale)	22
	Cannaceae	
92	Canna (Canna discolor, C. flaccida)	18
	Orchidaceae	
93	Lady's slipper (Cypripdium acaule)	20
94	Lady's slipper (C. spectabile)	22
95	Orchid (Cattleya trianei)	40
96	Orchid (Cymbidium gigunteum)	40
97	Orchid (Dendrobium nobile)	38
	Angiospermae: Dicotyledoneae	
	Piperaceae	
98	Peperomia (Peperomia sanderiana)	24
	Pepper (Piper nigrum)	128
	Salicaceae	
99	Poplar (Populus spp)[4]	38
100	Willow (Salix alba)	76
101	Willow (S. cordiophylla)	38
102	Willow (S. viminalis)[5]	38
103	Juglandaceae	
104	Hickory (Carya spp)[5]	32
105	Walnut (Juglans spp)[6]	32
106	Walnut (J. californica)	34

	Species	Number
	Angiospermae: Dicotyledoneae (continued)	
	Betulaceae	
107	Alder (Alnus cordata)	42
108	Alder (A. glutinosa, A. incana)	28
109	Alder (A. japonica)	56
110	Alder (A. maritima)	28
111	Alder (A. rubra, A. rugosa)	28
112	Alder (A. spaethii)	56
113	Alder (A. viridis)	14
114	Birch (Betula alba)	84
115	Birch (B. fontinalis)	28
116	Birch (B. grossa)	42
117	Birch (B. lenta)	28
118	Birch (B. nigra)	28
119	Birch (B. papyrifera)	28, 42
120	Hornbeam (Carpinus spp)[7]	16
121	Hornbeam (C. betulus)	8, 64
	Fagaceae	
122	Beech (Fagus sylvatica)	24
123	Chestnut (Castanea crenata)	24
124	Chestnut (C. dentata, C. mollissima)	24
125	Oak (Quercus spp)[8]	24
	Ulmaceae	
126	Elm (Ulmus spp)[9]	28
127	Elm (U. americana)	56
	Moraceae	
128	Fig (Ficus carica)	26
129	Hemp (Cannabis sativa)	20
130	Jack fruit (Artocarpus integra)	56
131	Mulberry (Morus alba, M. indica)	28
	Urticaceae	
132	Ramie (Boehmeria nivea)	28
	Loranthaceae	
133	Mistletoe (Viscum album)	20
134	Mistletoe (V. articulatum)	24
	Polygonaceae	
135	Buckwheat (Fagopyrum esculentum)	16
136	Dock (Rumex aquaticus)	200
137	Dock (R. crispus)	60
138	Rhubarb (Rheum officinale)	22
139	Rhubarb (R. rhaponticum)	44
	Chenopodiaceae	
140	Beet (Beta vulgaris)	18
141	Pigweed (Chenopodium album)	54
142	Saltbush (Atriplex littoralis)	18
143	Spinach (Spinacia oleracea)	12
	Portulacaceae	
144	Purslane (Portulaca oleracea)	54
	Caryophyllaceae	
145	Carnation (Dianthus caryophyllus)	30, 90
146	Chickweed (Stellaria media)	40, 44
147	Pink (Dianthus deltoides)	30
148	Sweet william (D. barbatus)	30
	Nymphaeaceae	
149	Spatterdock (Nuphar advenum)	34
150	Waterlily (Nymphaea capensis)	28
151	Waterlily (N. lotus)	56
152	Waterlily (N. odorata)	84
	Ranunculaceae	
153	Anemone (Anemone caroliniana)	16
154	Anemone (A. hortensis)	16
155	Buttercup (Ranunculus bulbosus)	14, 16
156	Buttercup (R. repens)	32
157	Christmas rose (Helleborus niger)	32
158	Clematis (Clematis hybrida)	16
159	Clematis (C. paniculata)	16, 48, 64
160	Columbine (Aquilegia canadensis)	14
161	Columbine (A. vulgaris)	14
162	Larkspur (Delphinium ajacus)	16
163	Marsh marigold (Caltha palustris)	32, 48, 56

/1/ Spp: banksiana, bungeana, echinata, flexilis, jeffreyi, longifolia, murrayana, nigra, palustris, parviflora, peuce, pinaster, ponderosa, resinosa, rigida, sylvestris, strobus, tabuliseformis, thunbergii, virginiana. /2/ Spp: abies, glauca, mariana, pungens, sitchensis. /3/ Spp: candidum, elegans, giganteum, longiflorum, pardalinum, regale, speciosum. /4/ Spp: acuminata, adenopoda, alba, angulata, angustifolia, balsamifera, canadensis, candicans, canescens, catbayana, deltoides, grandidentata, jacki, koreana, lasiocarpa, laurifolia, maximowiczii, nigra, sieboldi, tomentosa, tremula, tremuloides. /5/ Spp: alba, glabra, laneyi, ovata, ovalis. /6/ Spp: cinerea, intermedia, mandschurica, nigra, regia, rupestris, sieboldiana. /7/ Spp: caroliniana, cordata, japonica, laxiflo, orientalis, tschonskii, turczaninonvii. /8/ Spp: acutissima, alba, agrifolia, bicolor, borealis, cerris, chrysolepis, coccinea, douglasii, dumosa, engelmanii, garrayana, glandulifera, illicifera, imbricaria, incana, lobata, macrocarpa, maryiandica, michauxii, montana, nigra, palustris, pontica, prinoides, primus, robur, stellata, tomentosa, velutina. /9/ Spp campestris, carpinifolia, glabta, fulva, japonica, laciniata, laevis, procera, pumila, racemosas.

73. CHROMOSOME NUMBERS: GYMNOSPERMS AND ANGIOSPERMS (Continued)

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants," G. Allen and Unwin, Ltd., London, 1945.

Species	Number
Angiospermae: Dicotyledoneae (continued)	
164 Monkshood (Aconitum napellus)	32
165 Peony (Paeonia albiflora, P. moutan)	10
Berberidaceae	
166 Barberry (Berberis canadensis)	28
167 Barberry (B. vulgaris)	28
168 Mahonia (Mahonia aquifolium)	28
169 Nandina (Nandina domestica)	20
Magnoliaceae	
170 Cucumber-tree (Magnolia acuminata)	76
171 Magnolia (M. denudata, M. grandiflora)	114
172 Magnolia (M. soulangeana)	76
173 Sweet bay (M. virginiana)	38
174 Yellow-poplar (Liriodendron tulipifera)	38
Calycanthaceae	
175 Allspice (Chimonanthus fragrans)	22
176 Sweet-shrub (Calycanthus floridus)	22
Annonaceae	
177 Cherimoya (Annona cherimola)	14
178 Custard-apple (A. reticulata)	14
179 Papaw (Asimina triloba)	18
Lauraceae	
180 Avocado (Persea americana)	24
181 Camphor-tree (Cinnamomum camphora)	24
182 Cinnamon (C. zeylanicum)	24
183 Sweet-bay (Laurus nobilis)	42
Papaveraceae	
184 Poppy (Eschscholtzia californica)	12
185 Poppy (Papaver orientale)	42
186 Poppy (P. rhoeas)	14
187 Poppy (P. somniferum)	22
Capparidaceae	
188 Caperbush (Capparis spinosa)	38
189 Spider flower (Cleome spinosa)	20
Cruciferae	
190 Cabbage (Brassica oleracea var.)	18
191 Candytuft (Iberis amara)	14, 16
192 Candytuft (I. sempervirens)	22, 44
193 Radish (Raphanus sativus)	18
194 Shepherd's purse (Capsella bursa-pastoris)	16, 32
195 Turnip (Brassica rapus)	20
196 Wallflower (Cheiranthus cheiri)	14
197 Watercress (Nasturtium officinale)	32, 48, 64
Droseraceae	
198 Sundew (Drosera anglica)	40
199 Sundew (D. intermedia)	20
200 Venus' fly-trap (Dionaea muscipula)	30
Crassulaceae	
201 Kalanchoe (Kalanchoe aromatica)	34
202 Kalanchoe (Kalanchoe spp)	500
203 Sedum (Sedum pusillum)	8
Saxifragaceae	
204 Currant (Ribes americanum, R. nigrum)	16
205 Deutzia (Deutzia crenata)	130
206 Deutzia (D. gracilis)	26
207 Gooseberry (Ribes grossularia)	16
208 Hydrangea (Hydrangea paniculata floribunda)	72
209 Hydrangea (H. quercifolia)	36
Hamamelidaceae	
210 Sweetgum (Liquidambar styraciflua)	30
211 Witch-hazel (Hamamelis virginiana)	24
Platanaceae	
212 Aspen (Platanus acerifolia)	42
213 Sycamore (P. occidentalis)	42
Rosaceae	
214 Almond (Prunus amygdalus)	16
215 Apple (Pyrus malus)	34

Species	Number
Angiospermae: Dicotyledoneae (continued)	
216 Blackberry (Rubus occidentalis)	14
217 Cherry (Prunus avium)	16, 24, 32
218 Cherry (P. cerasus)	32
219 Cherry-laurel (P. laurocerasus)	176
220 Chokeberry (P. virginiana)	32
221 Crabapple (Malus asiatica, M. baccata)	34
222 Flowering almond (Prunus triloba)	64
223 Hawthorn (Crataegus crus-galli)	68
224 Hawthorn (C. cordata)	72
225 Hawthorn (C. oxyacantha)	34
226 Loquat (Eriobotrya japonica)	34
227 Mt. ash (Sorbus americana)	34
228 Peach (Prunus persica)	16
229 Pear (Pyrus communis)	34, 51
230 Plum (Prunus domestica)	48
231 Quince (Cydonia oblonga)	34
232 Raspberry (Rubus idaeus)	14, 21, 28
233 Raspberry (R. strigosus)	14
234 Rose (Rosa multiflora)	14
235 Spiraea (Spiraea japonica)	18
236 Strawberry (Fragaria virginiana)	56
237 Strawberry (F. vesca)	14
Leguminosae	
238 Alfalfa (Medicago sativa)	32
239 Bean (Phaseolus lunatus, P. vulgaris)	22
240 Broadbean (Vicia faba)	12
241 Clover (Trifolium aureum)	14
242 Clover (T. incarnatum, T. pratense)	14
243 Clover (T. repens)	32
244 Lentil (Lens esculenta)	14
245 Lespedeza (Lespedeza striata)	22
246 Locust (Robinia pseudoacacia)	20
247 Lupine (Lupinus angustifolus)	40
248 Lupine (L. luteus)	46
249 Pea (Pisum sativum)	14
250 Peanut (Arachis hypogaea)	40
251 Redbud (Cercis canadensis)	12
252 Silktree (Albizzia julibrissin)	26
253 Soybean (Glycine soja)	40
254 Sweetclover (Melilotus officinalis)	16
255 Sweetpea (Lathyrus odoratus)	14
Oxalidaceae	
256 Sorrel (Oxalis acetosella)	22
Tropaeolaceae	
257 Nasturtium (Tropaeolum majus)	28
Linaceae	
258 Flax (Linum usitatissimum)	30
Rutaceae	
259 Grapefruit (Citrus paradisi)	18, 27, 36
260 Lemon (C. limonia)	18, 36
261 Lime (C. aurantifolia)	27
262 Orange (C. aurantium)	18
263 Orange (C. sinensis)	45
Euphorbiaceae	
264 Castor-bean (Ricinus communis)	20
265 Euphorbia (Euphorbia splendens)	36
266 Poinsettia (E. pulcherrima)	28
267 Tung oil tree (Aleurites fordii)	22
Callitrichaceae	
268 Callitriche (Callitriche autumnalis)	6
Buxaceae	
269 Boxwood (Buxus sempervirens)	28
Aquifoliaceae	
270 Holly (Ilex aquifolium)	40
271 Holly (I. opaca)	36
272 Winterberry (I. verticillata)	36
273 Yapon (I. vomitoria)	40

Species	Number
Angiospermae: Dicotyledoneae (continued)	
Aceraceae	
274 Maple (Acer campestre)	26
275 Maple (A. carpinifolium)	52
276 Maple (A. circinatum)	26
277 Maple (A. grisseum, A. negundo)	26
278 Maple (A. platanoides)	26, 78
279 Maple (A. pseudoplatanus)	52
280 Maple (A. rubrum)	78, 104
281 Maple (A. saccharinum)	52
Hippocastanaceae	
282 Horsechestnut (Aesculus hippocastanum)	40
Balsaminaceae	
283 Balsam (Impatiens balsamina)	14
284 Jewelweed (I. biflora)	20
Vitaceae	
285 Grape (Vitis labrusca)	38
286 Grape (V. rotundifolia)	40
287 Grape (V. vinifera)	38, 57, 76
Tiliaceae	
288 Basswood (Tilia spp)[10]	82
289 Basswood (T. amurensis)	164
Malvaceae	
290 Cotton (Gossypium barbadense)	52
291 Cotton (G. hirsutum)	52
292 Hollyhock (Althaea rosea)	42, 56
293 Mallow (Malva sylvestris)	42
294 Okra (Hibiscus esculentus)	72, 130
Theaceae	
295 Camellia (Camellia japonica)	30
296 Tea (Thea sinensis)	30
Violaceae	
297 Pansy (Viola tricolor)	26
298 Violet (V. arvensis)	34
299 Violet (V. odorata)	20
Passifloraceae	
300 Granadilla (Passiflora quadrangularis)	18
301 Map pop (P. incarnata)	18
302 Passion fruit (P. edulis)	18
Begoniaceae	
303 Begonia (Begonia carminata)	42
304 Begonia (B. margaritae)	52
Cactaceae	
305 Cactus (Echinocereus angusticeps)	22
306 Cactus (E. engelmannii)	44
307 Cactus (Zygocactus truncatus)	24
Nyssaceae	
308 Tupelo (Nyssa sylvatica)	44
Myrtaceae	
309 Eucalyptus (Eucalyptus globulus)	20
310 Guava (Psidium guajava)	22
311 Myrtle (Myrtus communis)	22
Oenotheraceae	
312 Fuchsia (Fuchsia rosea)	44
313 Fuchsia (F. splendens)	22
314 Primrose (Oenothera biennis)	14
315 Primrose (O. pumila)	28
Umbelliferae	
316 Caraway (Carum carvi)	20
317 Carrot (Daucus carota)	18
318 Celery (Apium graveolens)	22
319 Dill (Anethum graveolens)	22
320 Parsnip (Pastinaca sativa)	22
321 Parsley (Petroselinum sativum)	23
Cornaceae	
322 Dogwood (Cornus controversia)	20
323 Dogwood (C. florida)	22
324 Dogwood (C. mas)	18
Ericaceae	
325 Blueberry (Vaccinium atrococcum)	48
326 Blueberry (V. angustifolium)	48
327 Rhododendron (Rhododendron spp)[11]	26

/10/ Spp: cordata, europaea, glabra, neglecta, oliveri, platyphyllos. /11/ Spp: arborescens, carolinianum, catawbiense, maximum, ponticu, roseum, vesey, viscosum.

73. CHROMOSOME NUMBERS: GYMNOSPERMS AND ANGIOSPERMS (Concluded)

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants." G. Allen and Unwin, Ltd., London, 1945.

	Species	Number
	Angiospermae: Dicotyledoneae (continued)	
328	Rhododendron (Rhododendron calendulaceum)	52
	Primulaceae	
329	Cyclamen (Cyclamen persicum)	48, 84
330	Primrose (Primula vulgaris)	22
	Plumbaginaceae	
331	Plumbago (Plumbago europaea)	14
	Ebenaceae	
332	Persimmon (Diospyros kaki)	90
333	Persimmon (D. virginiana)	60, 90
	Oleaceae	
334	Ash (Praxinus americana)	46
335	Ash (F. chinensis)	138
336	Ash (F. pennsylvanica)	46
337	Forsythia (Forsythia suspensa)	28
338	Forsythia (F. viridissima)	28
339	Fringe-tree (Chionanthus virginica)	46
340	Jasmine (Jasminum multiflorum)	52
341	Lilac (Syringa vulgaris)	46-48
342	Olive (Olea europaea)	46
343	Osmanthus (Osmanthus fortunei)	44
344	Privet (Ligustrum vulgare)	46
	Asclepiadaceae	
345	Milkweed (Asclepias incarnata)	22
346	Wax plant (Hoya carnosa)	22
	Convolvulaceae	
347	Cypress vine (Ipomoea sloteri)	58
348	Moonflower (I. speciosum)	30
349	Morning glory (I. purpurea)	30
350	Sweetpotato (I. batatas)	90
	Polemoniaceae	
351	Phlox (Phlox divaricata)	1440-[1]
352	Phlox (P. drummondii)	14, 28
353	Phlox (P. maculata)	14
	Borraginaceae	
354	Borage (Borago officinalis)	16
355	Myosotis (Myosotis alpestris)	24, 48, 72, 80
356	Myosotis (M. palustris)	22, 64

	Species	Number
	Angiospermae: Dicotyledoneae (continued)	
	Labiatae	
357	Coleus (Coleus blumei)	24
358	Lavender (Lavandula officinalis)	54
359	Peppermint (Mentha piperita officinalis)	72, 84
360	Peppermint (M. piperita vulgaris)	68, 72
361	Rosemary (Rosmarinus officinalis)	24
362	Thyme (Thymus serpyllum)	24
	Solanaceae	
363	Eggplant (Solanum melongena)	24
364	Pepper (Capsicum annuum)	24
365	Petunia (Petunia violacea)	14
366	Nightshade (Atropa belladonna)	72
367	Potato (Solanum tuberosum)	48
368	Tobacco (Nicotiana tabacum)	48
369	Tomato (Lycopersicon esculentum)	24
	Scrophulariaceae	
370	Foxglove (Digitalis purpurea)	56
371	Mullein (Verbascum thapus)	32
372	Snapdragon (Antirrhinum majus)	16
	Bignoniaceae	
373	Catalpa (Catalpa bignonioides)	40
374	Trumpet vine (Campsis radicans)	40
	Gesneriaceae	
375	African violet (Saintpaulia ionantha)	28
	Plantaginaceae	
376	Plantain (Plantago lanceolata)	24, 96
377	Plantain (P. major)	12
	Rubiaceae	
378	Button bush (Cephalanthus occidentalis)	44
379	Cinchona (Cinchona ledgeriana)	40
380	Coffee (Coffea arabica)	22
381	Gardenia (Gardenia intermedia)	22

	Species	Number
	Angiospermae: Dicotyledoneae (concluded)	
	Caprifoliaceae	
382	Cranberry (Viburnum trilobum)	18
383	Elder (Sambucus canadensis)	36
384	Honeysuckle (Lonicera sempervirens)	36
	Cucurbitaceae	
385	Cucumber (Cucumis sativus)	14
386	Gourd, bottle (Lagenaria vulgaris)	22
387	Muskmelon (Cucumis melo)	24
388	Pumpkin (Cucurbita pepo)	40
389	Squash (C. maxima, C. moschata)	40
390	Watermelon (Citrullus vulgaris)	22
	Campanulaceae	
391	Canterberry bell (Campanula medium)	34
392	Cardinal flower (Lobelia cardinalis)	14
	Compositae	
393	Aster (Aster laevis)	54
394	Aster (A. multiflorus)	10
395	Chrysanthemum (Chrysanthemum frutescens)	27
396	Chrysanthemum (C. leucanthemum)	36
397	Chrysanthemum (C. maximum)	90
398	Cosmos (Cosmos bipinnatus)	24
399	Dahlia (Dahlia variabilis)	64
400	Dandelion (Taraxacum officinale)	24
401	Guayule (Parthenium argentatum)	35, 38, 54 72, 108-111
402	Lettuce (Lactuca sativa)	18
403	Marigold (Tagetes erecta)	24
404	Sunflower (Helianthus annuus)	34
405	Yarrow (Achilles millifolium)	36, 54
406	Zinnia (Zinnia elegans)	24

74. CHROMOSOME NUMBERS: FUNGI

Values are haploid numbers taken from the 1940-1952 literature. Because of the difficulty in obtaining accurate counts (mainly at meiosis) of the typically small fungi chromosomes, values in many cases should be considered estimates. Reports of two chromosomes for haploid numbers have been questioned and, therefore, are not listed.

	Species	Number
1	Absidia spinosa	12
2	Achlya bisexualis	3
3	A. megasperma	5
4	A. recurva	4
5	Albugo evolvuli	8
6	A. portulacae	8
7	Allomyces arbuscula[1]	16
8	A. cystogenus	14
9	A. javanicus javanicus	13-21
10	A. javanicus macrogynus[2]	28
11	Amanita caesaria	16
12	Ascobolus magnificus	8
13	A. sterocarius	16
14	Aspergillus nidulans	4
15	Calonectria rigidiuscula	7
16	Ciliaria hirta	4
17	Coleosporium helianthi	8
18	C. sidae	8
19	C. vernoniae	8
20	Cudonia circinans	6
21	Dermatocarpon aquaticum	8
22	Dictyostelium discoideum	7
23	Eremascus albus	6
24	Giberella lateritium	6
25	G. roseum	6
26	Glomerella cingulata	4
27	Gymnosporangium clavipes	8
28	G. juniperi-virginianae	8
29	Gymnosporangium nidus-avis	8
30	G. transformans	8
31	Helotium citrinum	6
32	Helvella atra	6
33	H. crispa	6
34	H. lacunosa	8
35	Humarina leucoloma	8
36	Hypomyces solani	6
37	Isoachlya intermedia	6
38	Lamprospora constellatio	6
39	L. hansenii	6
40	Leotia lubrica	8
41	Lepiota lenticularis	4
42	Melanospora parvispora	4
43	Nectria episphaeria	7
44	N. flava	4
45	Neurospora crassa	7
46	N. sitophila	7
47	N. tetrasperma	6, 7
48	N. sp (8-spored)	7
49	Olpidiopsis achlyae	6
50	Otidea vitellina	8
51	Patella albida	8
52	P. melaloma	4, 6
53	P. scutellata	6
54	Paxina acetabulum	6
55	P. hispida	8
56	Penicillium cyclopium	6-7
57	Peziza micropus	8
58	P. ochracea	6
59	P. sanguina	8
60	P. succosa	8
61	P. vesiculosa	6
62	P. vesiculosa	8
63	Phaeobulgaria inquinans	6
64	Phyllactinia corylea	8
65	Phytophthora himalayensis	3
66	Plasmopara viticola	14-16
67	Pyronema omphalodes	6, 12
68	Rhizophydium coronum	6, 8
69	Saprolegnia litoralis	7
70	Schizophyllum commune	3
71	Sclerotinia trifoliorum	6, 8
72	Scodellina leporina	8
73	Septobasidium spp	5
74	Sepultaria arenicola	8
75	Sordaria fimicola	8
76	Spathularia clavata	6
77	Stigmatea geranii	4
78	Taphrina deformans	4
79	Thekopsora hydrangeae	4
80	Thraustotheca primoachlya	5
81	Torula utilis	8
82	Tremellodon gelatinosum	4
83	Uromyces aloes	6
84	Venturia inaequalis	4, 6

[1] N = 8-32 in various isolates. [2] N = 50 or more in certain polyploid isolates.

Part I: BACTERIA AND VIRUSES

Generation time for bacteria is the average interval between cell divisions.

	Organism	Culture Medium	Temperature °C	Generation Time min		Organism	Culture Medium	Temperature °C	Generation Time min
1	Aerobacter aerogenes	Broth or milk	37	16-18	52	Phytomonas tabacum	Broth	25	81
2		Glucose + peptone	37	17.3	53	Proteus vulgaris	Broth	37	21.5
3		Peptone	37	22-30	54		Peptone + phosphate	37	40
4		Synthetic	37	29-44	55	Pseudomonas fluorescens	Broth	30	40
5	Azotobacter spp	Mineral salts + sugar	25-30	240-348	56		Glucose broth	37	34-34.5
6	A. chroococcum	Glucose broth		27-39	57	P. pyocyanea	Broth	37	34
7		Sugar + urea	28	74	58		Glucose broth	37	31
8	Bacillus cereus	Broth	37	18.8	59		Lactose broth	37	34
9		Glucose broth	37	17-24.5	60	Rhizobium japonicum	Mineral salts + yeast + mannitol	25	344-461
10	B. megatherium	Broth	30	31					
11	B. mycoides	Broth	37	28	61	R. leguminosarum	Mineral salts + mannitol	25	79-187
12	B. subtilis	Glucose broth		26-32					
13	B. thermophilus	Broth	55	18.3	62	R. meliloti	Mineral salts + yeast + mannitol	25	107
14		Tryptophan + broth	54.5	16					
15	Clostridium amylobacter	Corn mash	37	51	63	R. trifolii	Mineral salts + yeast + mannitol	25	101
16	C. botulinum	Glucose broth	37	35					
17	C. welchii	Milk	37	35	64	Salmonella enteritidis	Broth	42	21.5
18	Corynebacterium diphtheriae	Serum + glucose broth	37	34	65	S. paratyphi	Broth	37	23
					66		Peptone	37	28
19	C. pseudodiphtheriae	Broth	37	37	67	S. sulpestifer	Broth	37	26
20	Diplococcus mucosus	Milk	37	32	68	S. typhi	Bile + pus	37	24.5
21	D. pneumoniae I	Broth	37	24.5	69		Broth	37	23.5
22		Serum	37	29	70		Glucose broth	37	29
23		Serum + broth	37	20.5	71		Glucose + peptone	37	33
24	D. pneumoniae II	Broth	37	33	72	Serratia marcescens	Milk	37	37
25		Glucose broth	37	30	73	Shigella dysenteriae	Milk	37	23
26		Serum + broth	37	23	74		Peptone + phosphate	37	37
27	Erwinia carotovora	Broth	37	57.5	75	Spirochaeta spp	Modified thioglycolate	37	528
28		Glucose broth	37	42	76	Staphylococcus albus	Glucose broth	37	24-25
29	E. amylovora	Broth	30	71-94	77	S. aureus	Broth	37	27-30
30	Escherichia coli	Broth	37	17	78		Glucose broth	37	32
31		Lactose broth	37	16	79	Streptococcus fecalis	Glucose-citrate broth	37	27
32		Milk	37	12.5	80		Milk	37	26.5
33	E. coli communior	Broth	37	16	81	S. hemolyticus	Beef heart broth	37	32
34	Lactobacillus acidophilus	Milk	37	66-87	82		Glucose broth	37	26
35	L. bulgaricus	Glucose milk	37	41-75	83		Glucose serum broth	37	34
36		Milk	37	39-74	84	S. lactis	Glucose milk	37	26
37		Peptone milk	37	50	85		Lactose broth	30	48
38		Tomato juice + milk	37	38-40	86		Milk	37	26
39		Yeast extract	37	37	87		Peptone milk	37	37
40	L. casei	Milk	25	38	88	S. liquefaciens	Milk	37	27
41	L. delbruckii	Wort	45	83	89	S. mastitidis	Glucose milk	37	35-37
42	L. pentoaceticus	Yeast extract	28	67	90	S. thermophilus	Milk	37	27
43	Mycobacterium tuberculosis[1]	Synthetic	37	792-932	91	Treponema pallidum	Rabbit skin	37	1800
					92		Rabbit testes	37	1980
44	Pasteurella lepisepticа	Broth + blood		24.4	93	Vibrio comma	Broth	37	21.2-38
45	Phytomonas campestris	Broth	23-25	165	94	V. costatus	Broth	27	42
46	P. campestre	Broth	25	98		Viruses			
47	P. glycineum	Broth	23-25	95	95	Influenza A (PR-8)	Allantoic membrane[2]	37	330-510[3]
48	P. phaseoli	Bean broth	25	160	96	A (5 strains)	Allantoic membrane[2]	37	300-360[3]
49		Broth	25	150	97	B (3 strains)	Allantoic membrane[2]	37	480-600[3]
50		Glucose broth	25	138	98	Swine	Allantoic membrane[2]	37	360[3]
51	P. sojae	Broth	23-25	82					

/1/ Human strain H-37. /2/ Chick embryo. /3/ For viral agents generation time is the time required for infected cells to release new virus.

Part II: PROTOZOA

	Organism	Substrate	Temperature °C	Cell Division per da		Organism	Substrate	Temperature °C	Cell Division per da
1	Astasia	Tryptophan + Ac[1]	25	3.1	11	Paramecium aurelia	Lettuce + bacteria	20[4]	0.72[4]
2	Chilomonas paramecium	NaAc[1] + mineral salts	24	3.5	12	P. caudatum	Mineral salts + bacteria[5]	25-28	1.8
3	Didinium nasutum	Hopkin's + paramecium	21	3.6	13		Oat medium + bacteria	26	2.3
4	Euglena gracilis	In dark, no Ac[1]	10	0.03	14	Polytomella uvella	Aerated peptone	22	4.4
5		In dark + Ac[1]	23	0.47	15		Non-aerated peptone	22	1.8
6		Wheat infusion	25	3.5	16	Stentor coeruleus	Peter's + ciliates	19	0.6-0.9
7	Glaucoma pyriformis	Yeast extract	25	6.1[6]	17		Modified Peter's[6]	18-20	0.7-2.1
8		Yeast extract	24.2	6.9	18		Hetherington's[6]	22	0.65
9		Yeast + yeast extract[3]	25.2	7.6-8	19	Stylonychia pustulata		25?	4.5-5
10	Leucophrys patula	Glaucoma	25	3.7	20	Tetrahymena geleii		24	5.7-10.9

/1/ Acetate. /2/ Phelp's strain, Hetherington's strain, 6.4 div./da. /3/ Or peptone. /4/ At 28°C, 2 div./da. /5/ B. subtilis. /6/ Plus ciliates.

Part I: PARAMECIUM AURELIA (After Beale.)

Nine varieties with 17 mating types have been found. Only one mating type has been found in Variety 7. Values in the table are maximum percentages of conjugating pairs formed in mixtures of two types of paramecia. "Inc." means incomplete mating reaction, not leading to conjugation; when Inc. is enclosed in parentheses (Inc.) it indicates a weak, tentative reaction involving only a small proportion of the animals. Intervarietal conjugation gives rise to hybrid nonviability or low viability, or low viability of F_2 or back-cross generations.

Group	Variety	A								B									
		1		3		5		7	9		2		4		6		8		
		Mating Type I	II	V	VI	IX	X	XIII	XVII	XVIII	III	IV	VII	VIII	XI	XII	XV	XVI	
A	1	I	0	95	0	0	40	0	0	0	0	0	0	0	0	0	0	(Inc.)	
		II	0	1	0	40	0	10	0	0	0	0	0	0	0	0	(Inc.)	0	
	3	V		0	95	0	0	0	0	0	0	0	0	0	0	0	0	0	40 Inc.
		VI			0	0	0	(Inc.)	0	0	0	0	0	0	0	0	0	0	
	5	IX				0	95	0	0	0	0	0	0	0	0	0	0	0	
		X					0	(Inc.)	0	0	0	0	0	0	0	0	0	0	
	7	XIII						0	0	0	0	0	0	0	0	0	0	(Inc.)	
	9	XVII							0	95	0	0	0	0	0	0	0	0	
		XVIII								0	0	0	0	0	0	0	0	0	
B	2	III									0	95	0	0	0	0	0	0	
		IV										0	0	0	0	0	0	0	
	4	VII											0	95	0	0	0	95 Inc.	
		VIII												0	0	0	95	0	
	6	XI													0	95	0	0	
		XII														0	0	0	
	8	XV															0	95	
		XVI																0	

Part II: PARAMECIUM BURSARIA (After Sonneborn.)

Six varieties with 23 mating types have been found. Only one mating type has been found in Variety V. In mixtures of the two mating types represented on the corresponding row and column, + = occurence of conjugation, - = no conjugation. Intervarietal conjugation between varieties II and IV is lethal.

Variety	I					II									III				IV	V	VI			
Mating Type	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	
I	A	-	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
	B	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	C	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	D	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
II	E					-	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-
	F					+	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
	G					+	+	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
	H					+	+	+	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
	J					+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-
	K					+	+	+	+	+	-	+	+	-	-	-	-	+	-	-	-	-	-	-
	L					+	+	+	+	+	+	-	+	-	-	-	-	+	-	-	-	-	-	-
	M					+	+	+	+	+	+	+	-	-	-	-	-	+	-	-	-	-	-	-
III	N													-	+	+	+	-	-	-	-	-	-	-
	O													+	-	+	+	-	-	-	-	-	-	-
	P													+	+	-	+	-	-	-	-	-	-	-
	Q													+	+	+	-	-	-	-	-	-	-	-
IV	R																	-	+	-	-	-	-	-
	S																	+	-	-	-	-	-	-
V	T																			-	-	-	-	-
VI	U																				-	+	+	+
	V																				+	-	+	+
	W																				+	+	-	+
	X																				+	+	+	-

Part III: PARAMECIUM CAUDATUM (After Gilman.)

Sixteen varieties with 31 mating types, but only one in Variety 10, have been found. In mixtures of the two mating types represented on the corresponding row and column, + = strong mating reaction and conjugation, ± = mating reaction but no conjugation, - = no mating reaction or conjugation.

Variety	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mating Type	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX	XXXI	XXXII
1	I	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	II	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	III	-	-	+	-	-	-	-	-	-	-	-	±	-	±	±	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
	IV	-	+	-	-	-	-	-	-	-	-	-	±	-	±	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-	-
3	V	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VI	-	-	-	-	+	-	-	-	-	±	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	VII	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	VIII	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	IX	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	X	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	XI	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XII	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	XIII	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XIV	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	XV	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-
	XVI	-	±	-	-	-	-	-	-	-	-	-	-	-	-	+	±	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-
9	XVII	-	-	±	-	-	-	-	-	-	-	-	-	-	±	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XVIII	-	±	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	XXI	-	±	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	XXII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XXIII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	XXIV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	XXV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
	XXVI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
14	XXVII	-	±	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	+	-	-	-	-
	XXVIII	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	-	-	-
15	XXIX	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	±	-	±	-
	XXX	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	-	-	-
16	XXXI	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+
	XXXII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	±	-	+	-	+	-

/1/ One mating type XIX has been found.

Part IV: PARAMECIUM CALKINSI

\+ = mating reaction and conjugation; - = noconjugation in mixtures of two mating types represented in the corresponding row and column.

Variety		1			2	
	Mating Type	I	II	III	IV	
1	I	-	+	-	-	
	II	+	-	-	-	
2	III	-	-	+	-	
	IV	-	-	+	-	

76. GENETICS OF PARAMECIUM (Concluded)

Part V: PARAMECIUM MULTIMICRONUCLEATUM

(Parts IV, V and VI after Wichterman.)

\+ = mating reaction and conjugation; - = none in mixtures of two mating types represented in the corresponding row and column.

Mating Type	I	II	III	IV
I	-	+	+	+
II	+	-	+	+
III	+	+	-	+
IV	+	+	+	-

Part VI: PARAMECIUM TRICHIUM

\+ = mating rention and conjugation; - = none in mixtures of two mating types represented in the corresponding row and column.

Mating Type	I	II	III
I	-	+	+
II	+	-	+
III	+	+	-

Part VII: INHERITANCE OF MATING TYPES

Section 1: Paramecium aurelia (After Sonneborn.)

a. Analysis of 4 caryonides from individual pairs of conjugants.

No. of Pairs	Number of Caryonides	
	I	II
1	4	0
18	3	1
21	2	2
13	1	3
3	0	4

b. Analysis of the two sister caryonides from each ex-conjugant.

Number of Ex-conjugants[1]	Number of Caryonides	
	I	II
55	2	0
70	1	1
34	0	2

/1/ Each ex-conjugant contains two macronuclei derived from a single fusion nucleus. When the ex-conjugant divides into two daughter cells, each cell contains one of the two marconuclei. All descendants of each daughter cell constitute a caryonide.

Section 2: Paramecium bursaria (After Jennings.)

Parental Types (Mating Types of the Conjugants)	Number of Pairs Yielding Clones of the Parental Mating Types	Numbers Yielding Clones of Non-Parental Mating Types
A X B	103	6
A X C	39	22
A X D	66	14
B X C	89	1
B X D	64	38
C X D	120	4
L X M	44	43
Total:	525	128

Part VIII: DIFFERENCES BETWEEN VARIETIES: PARAMECIUM BURSARIA

	Differences	Variety I	Variety II	Variety III
1	Time of day or night when animals can undergo mating reaction.	Daytime.	Daytime.	Any time of day or night.
2	Length of time of conjugation (at 26.5°C).	20-22 hours.	36 or more hours.	
3	Chromosomes	Intermediate between varieties II and III.	Thin and short.	Generally thick and long.

Part IX: GEOGRAPHICAL DISTRIBUTION OF VARIETIES

Section 1: Paramecium aurelia[1]

Variety	North America	South America	Western Europe	Japan	India
1	X	X	X	X	.
2	X	X	X	.	.
3	X	.	.	.	.
4	X	X	.	X	.
5	X	.	.	.	.
6	X	.	.	.	X
7	X	.	.	.	.
8	X	.	.	.	.
9	.	.	X	.	.

Section 2: Paramecium bursaria[2]

Variety	U.S.A.	China	Japan	Russia	Central Europe	Western Europe
I	X	X	X	.	.	.
II	X	.	.	.	.	.
III	X	.	.	.	.	.
IV	.	.	.	X	.	.
V	.	.	.	X	.	.
VI	.	.	.	.	X	.

Section 3: Paramecium caudatum[3]

Variety	U.S.A.	Japan	France
1	X	.	.
2	X	.	.
3	X	X	.
4	X	.	.
5	X	.	.
6	X	.	.
7	X	.	.
8	X	.	.

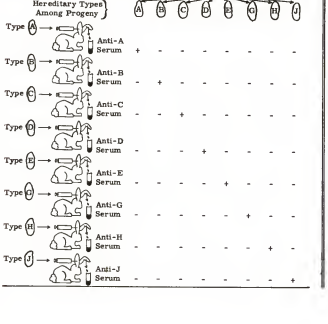
Variety	U.S.A.	Japan	France
9	X	.	.
10	X	.	.
11	X	.	.
12	.	X	.
13	.	X	.
14	X	.	.
15	.	.	X
16	.	.	X

/1/ After Sonneborn, Beale, and Schneller. /2/ After Jennings, Opitz, and Chen. /3/ After Gilman.

77. THE ANTIGENIC TYPES: PARAMECIUM AURELIA (RACE 51)

(After Sonneborn.)

Serum taken from a rabbit repeatedly injected with paramecia paralyzes paramecia of the same strain. The serum may or may not have a paralyzing effect on other strains. If a second rabbit is injected with a resistant strain, the serum obtained will paralyze paramecia of the second strain but not the first. This indicates interaction between paramecia antigens of rabbit antibodies. Each antigenically distinct strain is called a serotype. A culture of one serotype, derived from a single ancestral cell, may give rise to cells of different hereditary serotypes. The accompanying diagram illustrates a single cell of race 51 (serotype A) giving rise to the original A and seven distinctly different serotypes, B, C, D, E, G, H and J.



78. GENETIC SYSTEM INVOLVED IN CONTROL OF ANTIGENIC TRAITS: PARAMECIUM AURELIA (RACE 51) (After Beale.)

In Figure 1, the two conjugants do not exchange cytoplasm. This is normal. The 51A parent gives rise to 51A animals, whereas 51B parent gives rise to 51B animals. Inheritance therefore appears to be cytoplasmically determined. If a substantial amount of cytoplasm is exchanged between two mates, both would produce either type 51A or type 51B. In Figure 2, small amounts of cytoplasm are exchanged. One mate produces type 51A, while the other produces mostly type 51B and some type 51A. Evidence indicates that antigenic types differ only in cytoplasmic factors.



Fig. 1: Conjugation without Cytoplasmic Exchange



Fig. 2: Conjugation with Cytoplasmic Exchange

79. BLOOD GROUPS AND FACTORS: DISTRIBUTION IN VARIOUS POPULATIONS

Values are per cent of the population.

Group or Factor			Population																
General	Differentiated		American Indian[1]	Arabian, Baghdad	Australian Aborigine	Chinese	Egyptian, Cairo	English	Eskimo, S.W. Greenland	German, Berlin	Hawaiian	Hindu	Italian	Japanese	Norwegian	Russian	Swedish	U.S.A., Negro	U.S.A., White
								Blood Groups[2]											
1	O		23.5-98.5	34.1	53.1	30.0	26.6	46.7	36.3	36.5	36.5	31.3	41.2	31.2		33.7	37.9	49.3	45.0
2	A	A_1	1.5-76.5	30.8	44.7	25.0	35.7	41.7	54.6	42.5	60.8	19.0	39.4	38.4		38.4	46.7	26.0	31.4
3		A_2																	9.6
4	B		0-11.6	28.9	2.1	35.0	27.1	8.6	5.3	14.5	2.2	41.2	14.0	21.8		20.8	10.3	21.0	10.0
5	AB	A_1B	0	6.2	0	10.0	10.5	3.0	3.7	6.5	0.5	8.5	5.4	8.6		7.1	5.1	3.7	2.9
6		A_2B																	1.1
			Rh Positive																
7	Rh_1		1.1		4.0	0.9	11.5	2.5	1.0	2.0		2.9	1.3	0	1.5			45.9	2.2
8		Rh_1Rh_1	40.7		39.0	60.6	25.5	19.7	34.9	19.5		35.2	23.3	37.4	15.9			0.9	20.9
9	Rh_1	Rh_1rh	7.4		14.0		39.7	35.2		35.6		32.4	37.3		35.6			22.8	33.8
10	Rh_2		9.5		21.0	3.0	9.2	12.2	19.7	12.9		3.8	9.6	13.3	13.8			16.3	14.9
11		Rh_1Rh_2	38.1		15.0	34.1	8.2	13.6	44.4	13.9		16.2	11.8	47.3	14.7			4.4	13.9
12	Rh_2	Rh_2Rh_2	3.1		6.0			0.1		0.4		0	0.6					0	0.1
			Rh Negative																
13	rh		0		0	1.5	5.9	14.8	0	14.4		7.6	14.8	1.3	16.2			7.4	12.5
14	rh'		0		1.0	0		0.7	0	0.5		1.9	0.5	0	0.7			1.5	0.9
15	rh''		0		0	0		0	0	0.8			0.5	0	1.2			0.7	0.5
16	rhy		0		0	0		0	0				0.3	0.7				0	0
			Blood Factors (M-N Blood Groups)[3]																
17	M		60.0		3.0	33.2	28.3	30.5	67.6	30.2		42.7	28.9	29.0		32.2	36.1	28.4	29.2
18	N		4.9		67.4	18.2	23.1	21.4	2.4	19.7		10.7	17.1	21.1		21.2	16.9	21.9	21.3
19	MN		35.1		29.6	48.6	48.6	48.2	30.0	50.1		46.7	53.9	49.9		46.5	47.0	49.6	49.6

/1/ Blood group data from Tobe Indians (Argentina), Blackfeet (Montana), and Pueblo (New Mexico); Rh data from Mexican Indians; M-N data from U.S.A., tribe not specified. /2/ Equivalents in obsolete terminologies of Moss and Jansky are: O=Moss IV, Jansky I; A=Moss and Jansky II; B=Moss and Jansky III; AB=Moss I, Jansky IV. /3/ Other blood group systems are the P, Lutheran (Lua), Kell-Cellano (K, k), Lewis (Le^a, Le^b), Duffy (Fy^a, Fy^b), and Kidd (Jk^a, Jk^b). The approximate frequencies for U.S.A. whites are: P 49%; Lu^a 4%, Lu^b 96%; K 5%, k 95%; Le^a 47%, Le^b 68%; Fy^a 41%, Fy^b 59%; Jk^a 52%, Jk^b 48%.

80. HEREDITY OF BLOOD GROUPS AND FACTORS: APPLICATION IN DISPUTED PATERNITY

Children's Groups		If Parents' Groups Are:												
		OxO	OxA	OxB	AxA	AxB	BxB	OxAB	AxAB	BxAB	ABxAB	MNxMN	MNxMN	MxN	MxN	MxM	NxN
1	Can be:	O	A, O	B, O	A, O^1	AB, O^2	A^3, B	B, O	A, B	B^1, AB, A	A, B, AB	M, N, MN	M, MN	M, N	MN	MN	N
2	Cannot be:	A, B, AB	B, AB	A, AB	B, AB	None		A, AB	O, AB	O	O	None	N	M	M, N	N, MN	M, MN

/1/ This type not possible if either parent is genetically A/A. /2/ If one parent was genetically A/O and the other B/O, an O can result. /3/ This type not possible if one parent is genetically B/B.

81. THE Rh-Hr (CDE-cde) SYSTEM OF BLOOD FACTORS

Plus (+) indicates agglutination by antiserum; thus C+ = agglutination of red cells by anti-C (anti-rh') and presence of agglutinogen C, i.e., in the red cells. Minus (-) = no reaction with antiserum and absence of agglutinogen. In CDE notation, diagonal (/) separates genes contributed by one parent from those contributed by the other parent.

	Phenotypes and their Frequencies[4]; Classified by Agglutination Reactions with Antisera				Genotypes		
	1 Antiserum (Anti-D)	3 Antisera (Anti-C, D, E)	5 Antisera (Anti-C, D, E, c, e)	Wiener Terminology	Fisher-Race Terminology	Calculated Frequencies %
1	Rh_0 (D-), negative 14.9%	rr (C-D-E-), 13.4%	rr (C-D-E-e+e+)	r^{r}	cde/cde	13.4
2			$r'r'$ (C+D-E-c+e+)	$r'^{r'}$	Cde/Cde	0.02
3		rh' (C+D-E-), 1.1%	$r'r$ (C+D-E-c+e+)	r'^{r}	Cde/cde	1.1
4			$r''r''$ (C-D-E+c+e+)	$r''^{r''}$	cdE/cdE	0.003
5		rh'' (C-D-E+), 0.4%	$r''r$ (C-D-E+c+e+)	r''^{r}	cdE/cde	0.4
6			$r_y r$ (C+D-E+c+e+)	r_y^{r}	Cde/cdE	0.02
7			$r_y r'$ (C+D-E+c+e+)	$r_y^{r'}$	Cde/cdE	
8		rh'rh'' (r_y) (C+D-E+), 0.02%	$r_y r''$ (C+D-E+c+e+)	$r_y^{r''}$	CdE/cde	0.0003
9			$r_y r''$ (C+D-E+c+e+)	$r_y^{r''}$	CdE/cdE	0.0001
10			$r_y r_y$ (C+D-E+c+e+)	$r_y^{r_y}$	CdE/CdE	0.000001
11	Rh_0 (C-D+E+), 2.5%	R_0R_0 (C-D+E-c+e+)	$R_0^{R_0}$	cDe/cDe	0.1	
12			R_0^{r}	cDe/cde	2.4	
13	Rh_1 (C+D+E-), 51.2%	R_1R_1 (C+D+E-c-e+)	$R_1^{R_1}$	CDe/CDe	16.9	
14			R_1^{r}	CDe/Cde	1.1	
15		R_1R_0 (C+D+E-c+e+)	$R_1^{R_0}$	CDe/cDe	2.6	
16			R_1^{r}	CDe/cde	30.6	
17			R_0^{r}	cDe/cde		
18	Rh_2 (C-D+E+), 16.5%	R_2R_2 (C-D+E+c+e-)	$R_2^{R_2}$	cDE/cDE	2.7	
19			R_2^{r}	cDE/cdE	0.2	
20		R_2R_0 (C-D+E+c+e+)	$R_2^{R_0}$	cDE/cDe	1.1	
21			R_2^{r}	cDE/cde	12.5	
22			R_0^{r}	cDe/cdE		
23	Rh_0 (D+), positive 85.1%		$R_2^{R_2}$	CDE/cDE	13.9	
24			$R_2^{R_1}$	CDE/CDe		
25			R_2^{r}	CDE/cde		
26			$R_1^{R_1}$	CDe/cdE	0.9	
27			R_1^{r}	cDE/Cde		
28			R_0^{r}	cDe/CdE		
29	Rh_1Rh_2 (Rh_z) (C+D+E+), 14.9%	R_2R_1 (C+D+E+c+e+)	$R_2^{R_1}$	CDE/CDe	0.08	
30			R_2^{r}	CDE/cde	0.001	
31			R_1^{r}	CDe/CdE		
32		R_2R_2 (C+D+E+c+e-)	$R_2^{R_2}$	CDE/cDE	0.03	
33			R_2^{r}	CDE/cdE	0.0004	
34			R_2^{r}	cDE/CdE		
35		R_2R_z (C+D+E+c-e+)	$R_2^{R_z}$	CDE/CDE	0.0001	
36			$R_2^{r_y}$	CDE/CdE	0.00002	

/1/ Frequencies are percentages showing occurrence in American whites. The percentage of whites reacting positively to various antisera are: 70% anti-C (anti-rh'); 65% anti-D (anti-Rh_0); 30% anti-E (anti-rh''); 80% anti-c (anti-hr'); 97% anti-e (anti-hr'').

82. GENETIC LINKAGE: MAN

Part I: COMPLETELY SEX-LINKED GENES (X-CHROMOSOME TRANSMISSION)

	Mutation	Gene Symbol	Phenotypic Expression: Hemizygote XY	Heterozygote XX	Homozygote XX
1	Classical hemophilia	h	Severe bleeder.	Normal.	Severe bleeder.
2	Mild hemophilia	h^m	Mild bleeder	Occasionally slightly affected.	Unknown.
3	Plasma thromboplastin component deficiency		Severe bleeder.	Slightly affected.	Unknown.
4	Retinitis pigmentosa		Choroideoretinal degeneration.	Tapetal reflex.	Unknown.
5	Ocular albinism		Lack of pigment in globe.	Fundal changes.	Unknown.
6	Red-green color blindness	b	Color blindness.	Mildly affected.	Color blindness.
7	Hemeralopia		Night blindness with myopia.	Normal.	Unknown.
8	Megalocornea		Large cornea.	Occasionally affected.	Unknown.
9	Microphthalmia		Microphthalmia and blindness.	Normal.	Normal.
10	Choroidemia		Night blindness, constricted visual fields, blindness.	Depigmented retina.	Unknown.
11	Nystagmus		Severe nystagmus.	Slight nystagmus.	Unknown.
12	Optic atrophy		Blindness.	Occasionally blind.	Unknown.
13	Congenital retinal detachment		Retinal detachment and blindness.	Normal.	Blindness(?).
14	External ophthalmoplegia		Ophthalmoplegia, myopia, absent knee jerks.	Absent knee jerks.	Unknown.
15	Macular dystrophy		Loss of central vision.	Normal.	Unknown.
16	Childhood progressive muscular dystrophy		Muscular dystrophy.	Normal.	Unknown.
17	Peroneal atrophy		Peroneal atrophy.	Occasionally affected.	Unknown.
18	Idiocy		Idiocy with microcephaly.	Normal.	Unknown.
19	Alopecia congenita		Hairlessness.	Normal.	Unknown.
20	Anhidrotic ectodermal dysplasia		Widespread ectodermal defects.	Normal.	Unknown.
21	Ichthyosis simplex		Scaly skin.	Normal.	Scaly skin.
22	Keratosis follicularis (Lameris)		Multiple skin keratoses.	Normal.	Unknown.
23	White occipital lock of hair		White lock of hair at occiput.	Normal.	Unknown.

Part II: HOLANDRIC GENES (Y-CHROMOSOME TRANSMISSION)

	Mutation	Phenotypic Expression XY		Mutation	Phenotypic Expression XY
1	Ichthyosis hystrix gravior	Bark-like skin.	4	Keratoma dissipatum	Horny papules on hands and feet.
2	Hypertrichosis of the ears.	Hairy ears.	5	Color vision anomaly	Poor color discrimination.
3	Webbed toes	Webbed toes.			

Part III: INCOMPLETELY SEX-LINKED GENES (X- and Y-CHROMOSOME TRANSMISSION)

The concept of homologous segments of the X- and Y-chromosomes has become widely disseminated throughout the literature on human genetics. However, the accuracy of the original observations on which the concept is based has been questioned; therefore, data should be considered with great caution.

	Mutation	Gene Symbol	Phenotypic Expression: Heterozygotes XY	XX	Homozygotes XY	XX
1	Interstitial nephritis		Severe, usually fatal.	Unknown	Mild or no disease observed	Unknown
2	Total color blindness	ac	← Normal. →		← Day blind. →	
3	Xeroderma pigmentosa	xe	← Normal. →		← X. pigmentosa. →	
4	Oguchi's disease	og	← Normal. →		← Night blindness without myopia. →	
5	Recessive epidermolysis bullosa	ep	← Normal. →		← Skin blisters with scarring. →	
6	Dominant retinitis pigmentosa	Re	← Pigmented retina with blindness. →		← Unknown. →	
7	Recessive retinitis pigmentosa	re	← Normal. →		← Pigmented retina with blindness. →	
8	Recessive spastic paraplegia		← Normal. →		← Spasticity, exaggerated tendon. →	

83. MUTATION RATES: MAN

Knowledge of mutation rates in man as in other organisms is still considered provisional, and the traits for which estimates are available are a highly selected fraction of all genes. Estimates for chondrodystrophy, aniridia and neurofibromatosis may be more reliable than those for epilosis and Waardenburg's syndrome. In some cases, significant figures have been reduced although two digits do not imply greater accuracy than one. Reported estimates for autosomal recessive traits are probably not reliable. The error in these estimates is unknown but may be appreciable.

	Character	Method of Estimation [1]	Mutations per Gene in One Generation	Remarks
			Dominant Genes	
1	Epilosis	Direct	$0.4\text{-}0.8 \times 10^{-5}$	
2	Chondrodystrophy	Direct	4.9×10^{-5}	Estimates may be spuriously high because of some evidence of phenocopies.
3		Direct	4.2×10^{-5}	
4		Direct	7×10^{-5}	
5		Indirect	4.3×10^{-5}	
6	Pelger's nuclear anomaly	Direct	2.7×10^{-5}	
7	Aniridia	Direct	0.5×10^{-5}	
8	Retinoblastoma	Direct	4.3×10^{-6}	Estimate based on proposition that 75% of all sporadic cases of retinoblastoma are phenocopies.
9	Retinoblastoma	Direct	1.4×10^{-5}	Estimates by treating all cases as caused by mutation.
10		Direct	2.3×10^{-5}	
11	Waardenburg's syndrome	Direct	3.7×10^{-6}	
12	Neurofibromatosis	Direct	$1.3\text{-}2.5 \times 10^{-4}$	
13		Indirect	$0.8\text{-}1.0 \times 10^{-4}$	
14	Facio-scapulo-humeral progressive muscular dystrophy	Indirect	4.7×10^{-6}	
15		Indirect	4.7×10^{-6}	
16	Multiple polyposis of the colon	Indirect	$1.0\text{-}3.0 \times 10^{-5}$	
			Sex-linked Recessive Genes	
17	Hemophilia	Indirect	3.2×10^{-5}	Estimate may include three types of hemophilia: (a) classical sex-linked hemophilia caused by a deficiency of anti-hemophilic globulin, (b) a sex-linked clotting defect caused by a lack of "plasma thromboplastin component," and (c) an autosomally inherited clotting defect caused by a lack of "plasma thromboplastin antecedent."
18	Childhood progressive muscular dystrophy	Direct [2]	1×10^{-4}	
19		Indirect	1×10^{-4}	
20		Indirect	$4.5\text{-}6.5 \times 10^{-5}$	
21		Direct	3.2×10^{-5}	
22		Indirect	3.8×10^{-5}	

/1/ All indirect estimations make use of estimates of the relative fitness, and frequency at birth, of the trait, and assume that the population is in equilibrium. /2/ Not a true direct estimate but an approximation which overestimates the mutation rate.

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

	Locus	Symbol	Mutation and Phenotype
			Mouse, house (Mus musculus) [1]
			Linkage Group I
1	16	fr	Frizzle. Decreased proportion of coarser types of hair; vibrissae curled.
2	4, 3	sh-1	Shaker-1. Deaf, choreic head movements.
3	16, 12	c[2]	Albinism. Absence of pigmentation.
4		p	Pink-eye. Pink eyes; reduction of black or brown pigment in coat.
5		o	Oligodactyly. Homozygotes lack 5th (or 4th and 5th) toe on front and/or hind feet.
			Linkage Group II
6	0.16	d	Dilution. Clumping of pigment in coat color.
7		se	Short ear. Reduction of pinna.
			Linkage Group III
8	8	a	Spotting. Unpigmented areas on fur.
9	33	hr	Hairless. Shedding of hair at 10-14 days.
10	7	pi	Pirouette. Whirling movements, resembles waltzing.
11	18	W	Dominant spotting. Homozygous lethal.
12	16	lx	Hemimelia tibiae. Reduction of tibia generally associated with bent fibula.
13		ri	Reeler. Impaired locomotion through disturbed balance.
			Linkage Group IV
14	12	r	Rodless retina. Outer nuclear layer of retina rodless.
15		si	Silver. Absence or reduction of pigment granules.
			Linkage Group V
16		Ra[3]	Ragged. Affects coat texture.
17	3	kr	Kreisler. Deaf, prolonged running in circles.
18	5	a	Non-agouti. Determines pigment distribution of black, brown and yellow in individual hair.
19	10	un	Undulated. Tail undulations; sometimes hunchback; animals often runts.
20	3	we	Wellhaarig. Shortened whiskers at birth, later curved.
21	19	pa	Pallid. Pink eyes, agouti coat color.
22	8	fi	Fidget. Head shaking side to side, some circling.
23	17	hy-1	Hydrocephalus-1. Dome-shaped, or increased head size from ventricular distension.
24		Sd	Danforth's short tail. Affects urogenital system. Homozygotes lethal. Heterozygotes short-tailed or tailless.
			Linkage Group VI
25	11.6	bt	Belted. Dorsal white spotting in belt area.
26		Ca	Caracul. Hair lies in fluffy waves, straightens later. Whiskers curved.
27	0, 3	N	Naked. Hair breaks off at 10-14 days.
			Linkage Group VII
28	29	wa-2	Waved-2. Wavy coat.
29	20	sh-2	Shaker-2. Deaf, choreic head movements, whirling in circles.
30		Re	Rex. Curly whiskers in juvenile. Curly vibrissal and short curly guard hairs.
31		vt	Vestigial.
32		Tr	Trembler. Spastic paralysis in legs; more marked in hind pair.
			Linkage Group VIII
33	7	b[4]	Brown. Coat color brownish hue.
34		m	Misty. Dilutes fur color, produces white tail tip in heterozygotes.
35		an	Anemia. Small, pale, sterile.
			Linkage Group IX
36	4.3	T[5]	Brachyury. Short tail. Homozygotes inviable.
37	2(?)	Ki	Kinky tail. Possibly an allele of Fu. Homozygotes inviable.
38	3.9	Fu	Fused. Resembles short tail. Expression variable.
39		H-2	Histocompatibility-2. Determines susceptibility and resistance to tissue transplants.
			Linkage Group X
40	20	v	Waltzing. Deaf, moves in circles.
41		ji	Jittery. Muscular incoordination in righting after being placed on back.

	Locus	Symbol	Mutation and Phenotype
			Mouse, house (Mus musculus) [1] (concluded)
			Linkage Group XI
42	9	wa-1	Waved. Short whiskers, waved hair.
43		Wh	White. Snow-white fur; eyes pink, reduced in size.
			Linkage Group XII
44	45	je	Jerker. Deaf; resembles waltzing.
45		ru	Ruby-eye. Eyes vary between ruby and pink.
			Linkage Group XIII
46		Lp(s)	Loop-tail. Twisted tail, wobbling bead.
47	40, 23	py	Polydactyly.
48	6	ln	Leaden. Resembles maltese dilution (blue).
49		Sp	Spoketh. White spotting on belly, occasionally on back.
50	32	fx	Fuzzy. Thin and faintly wavy hair.
			Linkage Group XIV
51	28	cr	Crinkled. Modified hair structure.
52	15	f	Flexed-tail. Causes anemia and belly-spot.
53		cb	Congenital hydrocephalus. Lethal at birth.
			Linkage Group XX (Sex Chromosoms)
54	12	Bn	Bent-tail. Viability of homozygous females and bent-tail males much reduced.
55	5	Ta	Tabby. Coat of heterozygous females transversely striped. Homozygous females and tabby males with coat resembling crinkled (cr).
56	0(?)	Br	Brindled. Coat flecked with patches of light hair. Brindled males die prior to 3 weeks.
57	21	Mo	Mottled. Similar to brindled except that males die in utero; perhaps an allele of Br.
58	(?)	Jp	Jumpy. Behavior disorder manifest in hemizygous males at about 11 days and lethal at 25-32 days.
59		To	Tortoise shell. Similar to mottled but probably not allelic. Position not determined.
			Rabbit (Lepus cuniculus)
			Linkage Group I
60	0	c	Albinism. Coat color alleles vary from chinchilla to complete albinism.
61	14.4	y	Yellow fat.
62	42.8	b	Brown. Brown coat color.
			Linkage Group II
63	0	du	Dutch pattern. White belt on colored background.
64	1.2	En	English. Colored spots on white background.
65	14.3	l	Angora hair. Increased hair fiber length.
			Linkage Group III
66	0	r_1	Rex-1. Short plush-like coat.
67	17.2	r_2	Rex-2. Short plush-like coat.
			Linkage Group IV
68	0	a	Non-agouti. Coat color black.
69	14.7	dw	Dwarf. Small size, lethal shortly after birth.
70	29.9	w	Wide-banded agouti. Wide banding of agouti hairs.
			Linkage Group V
71	0	br	Brachydactyly. Abnormality of toes.
72	28.3	f	Furless. Fur restricted to extremities.
73	36.8	an	Erythrocyte agglutinogen.
			Linkage Group VI
74	0	E	Extension. Extension of dark pigment.
75	26.2	At	Production of atropisesterase.
			Guinea pig (Cavia porcellus) [1]
			Linkage Group I
76	42.4a	R	Rough fur at least on hind toes.
77		Px	Polley. Tendency to return of thumb, little toe and rarely big toe.
			Linkage Group II
78	24.4a	si	Silvered (stationary from birth). Incomplete recessive.
79		m	Modifier. Modifies rough fur effect. Homozygote high grade roughness.
			Rat, common (Rattus norvegicus) [7]
			Linkage Group I
80	0	p	Pink-eye. Coat yellow, eyes pink.
81	20.5	r	Red-eyed yellow. Coat yellow, eyes red.
82	21	c	Albino. Absence of pigment from coat and eyes.
83	24.3	l	Lethal. Skeleton imperfect.
84	66.3	w	Waltzing. Runs in circles.

/1/ Locus values for house mouse, guinea pig, fowl and parasitic wasp are recombination percentages between successive genes listed. Where two values appear, the first represents data from heterozygous females and the second from heterozygous males. /2/ c-o = 15, 20. /3/ Ra-a = 24. /4/ b-an = 7. /5/ T-Fu = 4.3. /6/ Lp-ln = 35. /7/ Jaundice (j), curly coat (Cu_2), cataract (Ca), blue dilution of coat (d), hooded coat pattern (h), cowlick (cw), and shaker (sr) have been found to be independent of linkage groups I-V and of each other and are provisionally regarded as markers of seven additional chromosome pairs.

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype
		Rat, common (Rattus norvegicus) [1] (concluded)
		Linkage Group II
85	0	Sh	Shaggy. Hair and vibrissae curved.
86	4	Cu	Curly. Hairs of coat and vibrissae curved.
87	14.3	an	Anemia. Lack of red blood cells. Young anemic.
88	28	in	Incisorless. Incisors lacking.
89	47	s	Silvered coat.
90	52	b	Brown. Chocolate pigmentation.
			Linkage Group III
91	0	n	Naked, except for short fuzzy coat.
92	45	hr	Hairless. Hair lost at about 4 weeks of age.
93	88	wo	Wobbly. Ataxic locomotion.
			Linkage Group IV
94	0	k	Kinky. Hairs of coat and vibrissae kinky.
95	34.1	st	Stub. Short stubby tail.
			Linkage Group V
96	0	A	Agouti. Fur color wild type, agouti.
97	44.6	f	Fawn. Tawny blue to fawn coat color.
			Silkworm (Bombyx mori)
			Linkage Group I (Z Chromosome)
98	0	os	Low degree of translucency of larva.
99	14	Ge	Giant egg. Length and width 1.26 and 1.11, respectively, times the normal egg.
100	36.4	e	Elongate. First and second abdominal segments of larva unusually elongated.
101	38.7	Vg	Vestigial. Wings poorly developed.
102	49.6	od	Translucent. Skin of larva shows high degree of translucency.
			Linkage Group II
103	0	P	Plain. Full green larva white. +p, p^B, p^M, p^S, p^{Ss} multiple or pseudo-alleles of p.
104	6.1	S	New striped. Dark stripe on larva. Heterozygote almost as dark as homozygote.
105	6.9	Gr	Gray egg. Milky white shell, dark serosa pigment.
106	25.6	Y	Yellow blood. Deep yellow hemolymph in larva.
107	26.7	oa	Mottled translucent. Mottled translucency on larval skin.
108	31.8	Rc	Rusty. Yellowish-brown cocoon, lighter inner layer.
			Linkage Group III
109	0	Ze	Zebra. Black band on anterior end of each segment. Pair of black spots on ventral side of each larval segment.
110	0	ap	Apodal. All thoracic legs rudimentary.
111	22.8	lem	Lemon. Greenish-yellow coloring over skin visible from second instar.
			Linkage Group IV
112	0	L	Multilunar. Pairs of large brownish or yellowish round spots on thoracic and abdominal segments.
113	25.8	sk	Stick. Larva body slender and hard.
114	33.1	Spc	Speckle. Many dark spots on larval skin. Female sterile.
			Linkage Group V
115	0	pe	Pink-eyed. White egg. Pigment absent from serosa.
116	4.7	ok	Kinshiryu. High degree translucency of larva.
117	31.7	re	Red egg. Reddish-brown serosa.
118	40.8	oc	Chinese. High degree translucency of larva.
			Linkage Group VI
119	0	E	Plain supernumerary legs. Supernumerary legs in 1st and 2nd abdominal segments of larva. pE^{2s}, pE^{D}, pE^{R}, pE^{Kp}, pE^{N} multiple of pseudo-alleles of E.
120	1.4	Nc	No crescent supernumerary legs. Supernumerary leg in the 2nd abdominal segment.
121	3.0	$+^M$	Tetra molting. Shortened type, larva pupates after 4th molt. M^3, M^5 multiple or pseudoalleles of $+^M$.
122	8	b_2	Brown egg 2. Grayish-brown pigment in serosa.
123	13.6	F	Flesh. Cocoon color reddish-yellow or salmon.
124	17.7	l-k	Lethal-k. Embryo killed few days before hatching.
			Linkage Group VII
125	0	q	Quail. Larval body tinted reddish-purple and covered with shredlike lines.
126	7.0	Gb	Green b. Greenish cocoon color.
127	21	obt	B_2-mottled. Moderate degree translucency of larva. Not lethal.
128	0	ae	Amylase negative. Amylase in digestive fluid weak.
129	1.1	be	Amylase negative. Amylase in body fluid (hemolymph) weak.
			Linkage Group IX
130	0	l	Yellow inhibitor. Suppression of yellow blood and yellow cocoon.
131	5.9	l-a	Dominant chocolate. Like chocolate, head black.
132	6.7	hd	Dilute black. Whole larval body dilute black.
133	7.4	og	Giallo Ascoli. High degree translucency. Female almost sterile.
			Linkage Group X
134	0	w_1(w-1)	White egg 1. No pigment in serosa, white eyes in moth.
135	0.0+	fl	Wingless. Fore and hind wings absent in pupa and moth.
136	3.4	w_2(w-2)	White egg 2. Egg gradually changes from white to light reddish color. White eyes in moth.
137	6.9	w_3(w-3)	White egg 3. Light purplish-brown egg. Black eyes in moth.
			Linkage Group XI
138	0	K	Knobbed. Dermal protuberances appear on dorsal sides of several segments of larva, pupa and moth.
139	5.5	Bu	Burnt. Larva skin from 2nd to 5th segments shows burn-like scar.
140	17.1	hp	Black pupa.
141	24.0	mp	Microporous. Small wings.
			Linkage Group XII
142	0	Ng	No glue. Eggs easily separated from papers because of poor development of mucous glands in females.
143	14.0	C	Golden egg. Cocoon golden yellow outside, nearly white inside.
144	52.1	rd	Clumpy. Irregular egg shape and highly variable.
			Linkage Group XIII
145	0	ch	Chocolate. Newly hatched larva reddish-brown.
146	11.3	cf	Crayfish. Fore and hind wings swollen and protrude laterally from body in pupa.
			Linkage Group XIV
147	0	Di	Dirty. Irregular black lines and dots cover dorsal surface of larva.
148	2.7	U	Urea. Dark brown pigments cover dorsal and lateral sides of larva.
149	10.7	odk	Mottled. Low degree translucency.
			Linkage Group XV
150	0	Se	White side egg. Egg surface irregular and with many furrows.
151	7, 8	Gc	Green c. Green cocoon.
			Parasitic wasp (Habrobracon juglandis) [1]
			Linkage Group I
152	12	Sk	Speckled. Bright red flecks of pigment in white eye.
153	13	r	Reduced. Small wings. Reduced, irregular venation.
154	30	gl	Glass. Small eyes, lacks facet outlines.
155	x		Sex gene. Nine factors known. Determine sex differences.
156	10	fu	Fused. Antennal segments fused. Tarsal segments lacking or fused.
157	22	sb	Stubby. Males with antennae 7-9 segments long. Females with antennae 5-7 segments long.
158	42	bl	Black. Body color.
159	30	le	Lemon. Body color pale lemon-yellow.
160	12	c	Cantaloup. Eyes light pink, darken to deep red.
161	14	l	Long. Antennal segments elongated. Leg segments longer and thinner than wild type.
162	3	n	Narrow. Narrow wings, cuts off irregular slices of costal and inner wing margins.
163	7	bo	Honey. Body lacks black pigment entirely.
164	8	vl	Veinless. Wing veins missing, except along costal margin.
165	15	ro	Rough. Fourth radius vein absent and adjacent veins roughened.
166	12	bu	Bulged. Eyes abnormally bulged transversely.
167	37	cr	Crescent. Eyes small. Pigment in ocelli reduced, crescent-shaped.
168	41	sl/co	Semilong. Antennal and leg segments lengthened.

/1/ Locus values for house mouse, guinea pig, fowl and parasitic wasp are recombination percentages between successive genes listed. Where two values appear, the first represents data from heterozygous females and the second from heterozygous males. /7/ Jaundice (j), curly coat (Cu_2), cataract (Ca), blue dilution of coat (d), hooded coat pattern (h), cowlick (cw), and shaker (sr) have been found to be independent of linkage groups I-V and of each other and are provisionally regarded as markers of seven additional chromosome pairs.

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype
		Parasitic wasp (Habrobracon juglandis) [1] (concluded)
		Linkage Group I (concluded)
169	33	al/co Coalescent. Antennal segments coalescent.
170	32	ct Cut. Outer wing margin indented or straightened, giving cut appearance.
171	37	rd Red. Color varies from light red to dark red or almost black with temperature.
172	7	gy Gynoid. Short antennae in male, resembling female. Abdominal sclerites resemble female.
173		ac/el Aciform. Terminal half of antennae very slender, needle-like.
174		Eyeless. Heads malformed. Eye rudiments present.
		Linkage Group II
175	28	k Kidney. Kidney eye shape.
176	5	dw Dwindling. Irregularity and fusion of antennal segments.
177	11	m Miniature. Reduced body size. Semi-lethal, may die as pupa.
178		o Orange. Eyes orange varying to pink and red.
		Linkage Group III
179	25	bk Broken. Outer margin of primary wing broken and wings fragile.
180		wh/pl White. White eye. Ocelli colorless.
181	9	Pellucid. Compound eyes semi-transparent.
182		st Stumpy. Extreme reduction of tarsal segments.
		Linkage Group IV
183	23	sv Shot-veins. Wing veins broken and distorted
184	27	td Truncated. Wings extremely reduced, irregular in shape, (not truncate, tr).
185		ma Maroon. Light ocelli. Compound eyes deep reddish brown.
		Linkage Group V
186	22	wa Wavy. Wings shortened. Costal margin wavy.
187		br Broad. Thorax abnormally broadened.
		Linkage Group VI
188	40	ta Tapering. Antennae deficient with much fusion and irregularity of segments distally.
189		un^2 Undulating-2. Surface of wings in undulating waves.
		Linkage Group VII
190		pk/ew^3 Pink. Compound eyes pink.
191		Extended wings. Wings extended in active wasps.
		Linkage Group VIII
192	18	wt Wet. Wing microchaetae very long and irregular giving wet appearance.
193		bf Black feet. Tarsi abnormally black.
		Domestic fowl (Gallus gallus) [1]
		Linkage Group I (Sex Chromosome)
194	13	ko Head streak in down.
195	10	B Barring.
196	1d	Inhibitor. Inhibits melanin in dermis.
197	27	br Brown eye.
198	10	L_i Light down. In chicks not black.
199	16	S Silver. Plumage color.
200	11	K Slow feathering.
201		sd Dilution to blue.
202		n Naked.
203		al Albinism. Incomplete.
204		dw Dwarf.
205		xl Lethal, after three weeks.
206		sh Shaker. Lethal nervous disorder.
207		j Jittery. Lethal nervous disorder.
		Linkage Group II
208		Cp Creeper. Achondroplasia.
209	0.4	R Rose comb.
210	30	U Uropygial. Bifurcation of uropygial papilla.
		Linkage Group III
211	46	fr Fray. Defective wing and tail feathers.
212	12.5	Cr Crest. Top-knot and cerebral hernia.
213	17	I Confinant white. Plumage.
214		F Frizzling. Recurved feathers.
		Linkage Group IV
215	5	O Blue eggshell color.
216	33	P Pea comb.
217	46	ma Marbling. Pattern in down of chick.
218	46	Na Naked neck. Pteryiae reduced.

Locus	Symbol	Mutation and Phenotype
		Domestic fowl (Gallus gallus) [1] (concluded)
		Linkage Group V
219	43	Na Naked neck. Pteryiae reduced.
220	11	b Silkie. Barbules lack booklets.
221		Fl Flightless. Remiges break off.
		Linkage Group VI
222	26	D Duplex comb. Bifurcation of comb.
223	33	M Multiple spurs.
224		Po Polydactyly.
		Fruit fly (Drosophila melanogaster)
		X Chromosome (Element A)
225	0	1(1)J1 Lethal (1) Jacobs-Muller. Almost complete lethal.
226	0	y Yellow. Body yellow, bristles and larval mouth parts brown.
227	0+	ac Achaete. Postdorsal centrals missing, fewer intra-ocellar hairs.
228	0±	Hw Hairy-wing. Extra bristles and hairs along wing veins.
229	0+	sc Scute. Scutellars missing and other bristles fewer.
230	0±	svr Silver. Body, legs pale, bristles dark.
231	0+	su-s Suppressor of sable.
232	0+	l(1)7e Lethal (1)7e. Kills 1(1)7 early.
233	0+	saw Sawtooth. Serrated hair along wing edges.
234	0.1	su-b Suppressor of black.
235	0.1±	om Ommatidia. Eyes slightly rough.
236	0.1±	M(1)Bld Minute (1) blond. Extreme Minute. Deficiency.
237	0.3	l(1)7 Lethal (1)7. Melanotic tumors in larva; lethal.
238	0.3±	stu Stubaristia. Arista stubby, bristles short.
239	0.4±	tw Twisted. Abdomen twisted counterclockwise.
240	0.6	br Broad. Wings broad, short.
241	0.7	kz Kurz. Bristles short, slender.
242	0.7±	rey Rough eye. Small rough eye.
243	0.8	pn Prune. Eye color dark brownish red, often mottled.
244	0.9	gt Giant. Giant larvae, pupae, flies.
245	1.5	w White. White eyes, testes, larval Malpighian tubules.
246	1.7	rst Roughest. Eyes large, very rough.
247	3±	Co Confluens. Veins thick, deltoid.
248	3±	spl Split. Eyes rough, small. Bristles split.
249	3±	fa Facet. Eyes rough, wings nicked.
250	3±	Ax Abruptex. Wings arched, veins short.
251	3	N Notch.
252	4.6	dm Diminutive. Body, bristles small.
253	5±	M(1)3E Minute (1) at 3E. Slight Minute.
254	5±	su-dx Suppressor of deltex.
255	5.5	ec Echinus. Eyes and facets large, rough.
256	6.9	bi Bifid. Veins fused at wing base.
257	7±	M(1)4BC Minute (1) at 4BC. Strong Minute.
258	7.3±	peb Pebbled. Eyes slightly rough.
259	7.5	rb Ruby. Eye color clear ruby.
260	8	dow Downy. Bristles fuzzy. Female sterile.
261	11	rg Rugose. Wings thin, frayed.
262	12.5	bo Bordeaux. Eye color wine.
263	13.6	cx Curlex. Wings curled upward.
264	13.7	cv Crossveinless. Crossveins absent or traces.
265	15	rux Roughex. Eyes small, rough. Male sterile.
266	15.2±	Ext Extra. Veins augmented. Lethal in male.
267	16.3	vs Vesiculated. Wings inflated, divergent.
268	17	dx Deltex. Veins thickened, delta-like.
269	17.5	ov Oval. Eyes oval rough.
270	17.9	shf Shifted. Vein L3 fails to reach wing margin.
271	18.9	cm Carmine. Eye color dark ruby.
272	19.3	scp Scoped. Wings upturned, warped.
273	20	ct Cut. Wing scalloped at edges.
274	21	sn Singed. Bristles and haire curled. Female sterile.
275	23.1	oc Ocelliless. Ocelli absent. Female sterile.
276	23.1±	gg Goggle. Eyes bulging, head bristles fewer.
277	23.2	ptg Pentagon. Dark trident and thoracic spot.
278	23.8	ch-b Chilblained-b. Tarsi conglutinated.
279	24.3	dd Displaced. Antennae and eyes deformed.
280	25±	fbd Tiny-bristleoid. Bristles Minute type.
281	27.1±	con Condensed. Body, wings short, eyes rough.
282	27.5	t Tan. Body and antennae yellowish.
283	27.7	smx Almondex. Eyes reduced, narrow. Female sterile.
284	27.7±	lz Lozenge. Eyes narrow, ovoid. Female usually sterile.
285	28.1	dvr Divers. With y, wings strongly curled.
286	31±	flp Flap wings. Wings concave, eye slightly rough.

/1/ Locus values for house mouse, guinea pig, fowl and the parasitic wasp are recombination percentages between successive genes listed. Where two values appear, the first represents data from heterozygous females and the second from heterozygous males.

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Locus		Symbol	Mutation and Phenotype
			Fruit fly (Drosophila melanogaster) (continued)
			X Chromosome (Elements A) (concluded)
287	32a	ny	Notchy. Wing tips nicked.
288	32.8	rus	Raspberry. Eye color dark ruby.
289	33	v	Vermilion. Eye color bright vermilion, ocelli colorless.
290	33.2	dwx	Dwarfex. Body small, wings coarse.
291	33.4	sbr	Small bristle. Bristles small, some missing.
292	36.1	m	Miniature. Wings small, dark.
293	36.2	dy	Dusky. Wings small, dusky.
294	36.4	ty-1	Tiny-like. Bristles dark, thin.
295	38.3	fw	Furrowed. Eyes furrowed, scutellum shortened, bristles gnarled.
296	41.9	wy	Wavy. Wings waved, curled.
297	42a	kk	Kinky. Bristles bent or forked.
298	43	s	Sable. Body black.
299	44.4	g	Garnet. Eye color garnet pink.
300	44.5	ty	Tiny. Bristles, body small. Female sterile.
301	45.2	na	Narrow abdomen. Abdomen cylindrical. Female sterile.
302	47.9	pl	Pleated. Wings pleated.
303	49.3a	vb	Vibrissae. Vibrissae in tuft.
304	51.5	sd	Scalloped. Wing margins excised.
305	51.6	Bg	Bag. Wings short, blunt, inflated.
306	53.5	sl	Small-wing. Wings short, oblong. Eyes large.
307	54	mc	Microchaete. Hairs, bristles few and small.
308	54.4	un	Uneven. Eyes rough, blunt.
309	54.5	r	Rudimentary. Wings short, oblique. Female sterile.
310	55a	lf	Inflated. Wings inflated, veins thickened.
311	56a	cs	Creased. Wings longitudinally creased.
312	56.6	M(1)o	Minute(1)o. Minute Minute.
313	56.7	f	Forked. Bristles, hairs gnarled.
314	57	B	Bar. Eyes narrow.
315	59.2	od	Outstretched. Wings divergent.
316	59.2	ey	Small-eye. Eyes small, rounded.
317	59.4	Bx	Beadex. Wings excised.
318	59.5	fu	Fused. Wing veins fused at base.
319	62a	M(1)36f	Minute(1)36f. Slight Minute.
320	62.5	car	Carnation. Eye color dark ruby.
321	62.7	M(1)n	Minute(1)n. Extreme Minute.
322	63a	fo	Folded. Wings unexpanded.
323	64	sw	Short-wing. Wings trimmed, eyes small, rough.
324	64a	su-f	Suppressor of forked.
325	65.6	cf	Cleft. Wing venation increased.
326	66	bb	Bobbed. Bristles small, sclerites irregular.
			Chromosome II (Elements B and C)
327	0	net	Net. Extreme plexus venation.
328	0	al	Aristaless. Arlstae reduced, scutellars divergent.
329	0a	l(2)gl	Lethal(2) giant larva. Larval lethal.
330	0	ocr	Ochraces. Eye color light, darkening with age.
331	0.1	ex	Expanded. Wings broad, spread. Eyes rough.
332	0.3	da	Dachsous. Wings shorter, crosseins closer.
333	1.3	S	Star. Eyes small, rough. Homozygous lethal.
334	1.3a	Su-S	Suppressor of Star.
335	1.3a	nst	Asteroid. Eyes small, rough.
336	2.3a	shr	Shrunken. Body small, wizened.
337	3.8a	shv	Short vein. Constant terminal gaps in veins L2 and L4.
338	4	ho	Heldout. Wings extended.
339	5a	fes	Female-sterile. Eggs do not develop.
340	6a	E-S	Enhancer of Star. Increases expression of Star.
341	7	Cy	Curly. Wings curled upward. Homozygous lethal.
342	8.3	l(2)ay	Lethal(2) anal. Lethal.
343	10a	Dt	Detached. Vein L2 does not reach margin.
344	10.5	ang	Angle wing. Wings held up from dorsal surface.
345	11	ed	Echinoid. Eyes large, rough.
346	11-12	M(2)C	Minute(2) Curry. Fairly strong Minute. Deficiency.
347	12	ft	Fat. Body short, fat. Scutellar bristles far apart.
348	12	G	Gull. Wings large, spread. Homozygous lethal.
349	12.9a	M(2)z	Minute(2)z. Medium Minute.
350	13	M(2)B	Minute(2) Bridges. Medium Minute. Deficiency.
351	13	dp	Dumpy. Wings truncated. Vortices on thorax.
352	13a	dw-24F	Dwarf in 24F. Eyes dull, body dwarf.
353	15	M(2)Sl	Minute(2) Schultz'l. Strong Minute.
354	15a	l(2)cg	Lethal(2)comb-gap. Lethal from cg stock.
355	16	Sk	Streak. Central streak on thorax. Homozygous lethal.
356	16a	tkv	Thick-veins. Veins thick, irregular.

Locus		Symbol	Mutation and Phenotype
			Fruit fly (Drosophila melanogaster) (continued)
			Chromosome II (Elements B and C) (continued)
357	16.5	cl	Clot. Eye color maroon, close to sepia.
358	17a	pi	Pied. Facets jumbled.
359	22	Sp	Sternopleural. Extra sternopleural bristles. Homozygous lethal.
360	22.3a	spd	Spade. Wings shortened. broad.
361	24	gt-4	Giant-4. Giant flies.
362	31	d	Dachs. Tarsi 4-jointed, venation shifted.
363	33a	fy	Fuzzy. Thoracic hairs fuzzy.
364	39a	fol	Folded wings.
365	39.3a	da	Daughterless. Homozygous females produce no daughters.
366	41	J	Jammed. Wing narrow strip.
367	43a	M(2)Sl1	Minute(2)Schultz'11. Slight Minute.
368	44	ab	Abrupt. Shortened L5 vein, scutellars few.
369	45a	oph	Ophthalmopegia. Eyes kidney-shaped or with appendage.
370	46a	rk	Rickets. Segments of legs flattened and bent.
371	46a	$l(2)bs^3$-d	Lethal(2) with bs^3-d. Lethal.
372	46a	M(2)e	Minute(2)e. Medium Minute.
373	48.5	b	Black. Body, legs, veins black.
374	48.7	j	Jaunty. Wings upturned.
375	50	el	Elbow. Wings bent, halter and balancers small.
376	50a	lm	Limited. Sternites small. Female sterile.
377	50a	M(2)Sl3	Minute(2)Schultz'13. Strong Minute.
378	50a	l(2)lf	Lethal(2)Humphrey. Pupal lethal.
379	50.5	Su-H	Suppressor of hairless. Homozygous lethal.
380	51	rd	Reduced. Bristles small, irregular. Female sterile.
381	51a	pu	Pupal. Wings unexpanded.
382	52a	pys	Polychaetous. Extra and double bristles.
383	52.5a	cr-u	Cream-underscored. Specific dilutor of w^a and Pale. Male sterile.
384	53	nub	Nubbin. Wings very small and thin with tendency to curve up or down.
385	53a	ck	Crinkled. Wings flimsy.
386	53a	rdo	Reduced ocelli. Ocelli reduced in size, color moved to region between ocelli.
387	53.1	l(2)Bld	Lethal(2) opposite T1;2) Bld. Lethal.
388	53.5	M(2)35	Minute(2)Schultz'5. Medium Minute.
389	53.9	hk	Hook. Bristles bent or barbed.
390	54.3a	brt	Bright. Eye color bright red.
391	54.5	pr	Purple. Eye color purplish ruby.
392	54.5a	rn	Rotund. Wings round, tarsi 3-jointed. Sterile.
393	54.7a	rb	Roughish. Eyes moderately rough.
394	54.8	Bl	Bristle. Bristles short, beaded. Homozygous semi-lethal.
395	54.9	Alu	Alula. Alula fused to wing. Wing warped.
396	54.9	Jag	Jagged. Wings nicked, eyes rough.
397	55	lt	Light. Eye color yellowish pink.
398	55a	tri	Trident. Thorax darkened.
399	55a	M(2)D	Minute(2)D. Body color and bristles pale.
400	55.1	ri	Rolled. Wing edges rolled, frayed.
401	55.1	M(2)S2	Minute(2)Schultz'2. Minute type. Deficiency.
402	55.1	M(2)S4	Medium Minute. Deficiency.
403	55.1	M(2)S8	Slight Minute. Deficiency.
404	55.1	M(2)S10	Minute(2)Schultz'10. Slight Minute. Deficiency.
405	55.1	stw	Straw. Body, wings, bristles yellow.
406	55.2a	blt	Blot. Wings infected, blackened.
407	55.2a	Cu	Curl. Lateral compression and indentation-fold of unfolded imaginal wing.
408	55.3	tk	Thick. Legs, tarsi, thickened, wings short.
409	55.3	pk	Prickle. Bristles, hairs irregular.
410	55.4	ap	Apterous. Wings, balancers missing.
411	55.6	m-sf	Misformed. Eyes misformed, wings crumpled.
412	55.7a	bur	Burgundy. Dull, darkish-brown eye color.
413	55.9	tt	Tarsi irregular. Tarsal segments fused, eyes rough.
414	56a	lbd	Lightoid. Eye color clear, translucent yellowish pink. Ocelli colorless.
415	56a	M(2)Sl2	Minute(2) Schultz'12. Slight Minute.
416	56.5a	std	Staroid. Eyes small, very rough.
417	56.6a	ta	Tapered. Wings narrow and pointed. Veins close. Male sterile.
418	57a	dil	Specific dilutor. Dilutor of bw and w alleles.
419	57.1	buo	Burnt orange. Eye color orange-brown.
420	57a	M(2)38b	Minute(2)38b. Extreme Minute.
421	57.5	cn	Cinnabar. Eye color bright scarlet. Ocelli colorless.
422	58a	puf	Puff. Wings blistered.
423	58.5	blo	Bloated. Wings ballooned, extra veins.

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Locus	Symbol	Mutation and Phenotype
		Fruit fly (Drosophila melanogaster) (continued)
		Chromosome II (Elements B and C) (continued)
424	58.6±	am	Smoky. Body color dark.
425	58.7–60.2	Np	Notopleural. Bristles short, wings broad. Homozygous lethal. Deficiency.
426	60.1±	at	Arctus oculus. Number of facets reduced.
427	60.5±	arch	Arcb. Wings downcurved in both axes.
428	60.7	ad	Arcod. Wings arched, broad, short. Cross-veins close.
429	60.8	chl	Chaetelle. Bristles very small. Slight plexus.
430	61±	whd	Withered. Wings warped or shrunken.
431	61.5±	tom	Tomboy. Homozygous females with male-like pigmentation of posterior tergites.
432	62	en	Engraved. Scutellar notch, broken veins, extra sex comb.
433	62±	upw	Upward. Wings upturned.
434	63±	l(2)rn	Lethal(2) with rotund. Lethal.
435	65±	Bkd	Blackoid. Dark body color.
436	65±	M(2)40c	Minute(2)40c. Minute type.
437	65.2	po	Pale-ocelli. Ocelli nearly colorless.
438	66.7	sca	Scahroua. Eyes rough, some bristles missing.
439	67	vg	Vestigial. Wings, halancers vestigial.
440	67	l(2)C	Lethal(2) Curry. Lethal before pupal stage.
441	69.7	wx	Waxy. Wings heavy, waxy. Male sterile.
442	70±	Uf^{H20}	Upturned Uf^{H20}. Wings curled.
443	70±	$l(2)mr^{L2}$	Lethal(2) with morula^{L2}. Lethal.
444	70.8	Pfd	Pufdi. Wings puffed, divergent. Homozygous lethal.
445	71	hat	Hat. Wings extended, bent back.
446	71.1	cg	Comb-gap. Sex comhs large. Gap in wing vein L4. Female sterile.
447	71.2±	dr	Droopy. Wings spread wide apart and droopng.
448	71.5±	sf	Safranin. Eye color dark chocolate.
449	72	L	Lobe. Eyes small, nicked at anterior edge.
450	72.3	an	Knot. Veins L3 and L4 close. Eyes oblique.
451	72.5	ch	Chubby. Larva, pupa, adult short.
452	73±	dke	Dark eye. Eye color soft, dark, dull, with tiny fleck.
453	74±	gp	Gap. Vein L4 hroken.
454	75.5	c	Curved. Wings thin, spread, lifted, curved.
455	76±	Wr	Wrinkled. Wings wrinkled. Suppresses Lobe.
456	77.5	M(2)S7	Minute(2)Schultz^{7}. Strong Minute.
457	79±	pw-c	Pink-wing-c. Eye color dilute, wings shori, blunt.
458	80±	fr	Fringed. Wing margins ragged.
459	81±	fj	Four-jointed. Tarsi 4-jointed. Wings short.
460	81±	rf	Roof wings. Wings drooped at sides.
461	82±	wt	Welt. Eyes seamed, reduced.
462	83±	ahr	Abero. Abdominal hands irregular. Wings frayed, eyes rough. Female sterile.
463	83±	ow	Narrow. Wings narrow.
464	86.5	f-f	Intensifier or forked.
465	91.5	sm	Smooth. Abdomen hairless.
466	92.3	M(2)173	Minute(2)173. Moderate Minute.
467	93.3	hy	Humpy. Thorax ridged, wings truncated.
468	99±	l(2)Su-H	Lethal(2) from suppressor of hairless. Lethal.
469	99.2	a	Arc. Wings broad, heot down, crossveins closer.
470	99-101.2	M(2)1	Minute(2)1. Extreme Miute. Deficiency.
471	100.5	px	Plexus. Network of extra veins.
472	101±	ps	Patulous. Wings spread wide apart.
473	101.2	$M(2)1^{2}$	Minute(2)1^{2}. Slight Minute.
474	104	hv	Heavy vein. Veins thick, posterior crossveins. oblique.
475	104±	l(2)hw	Lethal(2)hrown. Probable deficiency. Lethal.
476	104.5	bw	Brown. Eye color hrownish to garnet.
477	104.7	mi	Minus. Bristles hairlike. Body small.
478	105.5	shh	Abhreviated. Bristles slightly reduced. Female sterile.
479	106.3	slt	Slight. Body small, bristles reduced.
480	106.4	pd	Purpleoid. Eye color dark pink, like purple.
481	106.7±	ll	Lanceolate. Wings narrow, pointed.
482	106.7	mr	Morula. Eyes rough, bristles small.
483	106.9	l(2)ax	Lethal(2)ax. Very early larval lethal.
484	107	sp	Speck. Black speck in wing axil. Body color olive.

Locus	Symbol	Mutation and Phenotype
		Fruit fly (Drosophila melanogaster) (continued)
		Chromosome II (Elements B and C) (concluded)
485	107.2	or	Orange. Bright orange eye color.
486	107–107.4	Fx	Flexate. Veostion like hs. Veins thickened, broken. Homozygous lethal. Deficiency.
487	107.3	bs	Blistered. Wings blistered, small. Extra veins.
488	107.3±	Pin	Pin. Thoracic bristles pin-like.
489	107.4	ba	Balloon. Wings inflated, extra veins.
490	108±	M(2)33a	Minute(2)33a. Strong Minute. Deficiency.
		Chromosome III (Elements D and E)
491	0	ru	Roughoid. Eyes small, rough. Erupted facets.
492	0	mp	Micropters. Wings small, ballooned. Tarsi 4-jointed.
493	0±	aa	Anorists. Aristae small, without branches.
494	0.2	ve	Veinlet. Longitudinal wing veins interrupted.
495	1.4	R	Roughened. Eyes rough. Homozygous semilethal.
496	17±	rai	Raisin. Deep hrown eye color.
497	19.2	jv	Javelin. Bristles and hairs cylindrical.
498	20	dv	Divergent. Wings spread.
499	20±	Me	Medre. Eye color hrownish, 7 flecks. Homozygous lethal.
500	23	Hn	Henna. Eye color dull, dark. Homozygous lethal.
501	25±	be-3	Benign tumor in 3. Non-lethal melanotic tumors.
502	26	se	Sepia. Eye color hrownish red, darkening to black.
503	26±	su-t	Suppressor of tan.
504	26.5	h	Hairy. Extra hairs on scutellars, veins, pleurae, head.
505	27±	abd	Abdominal. Abdominal hands broken, etched.
506	35	re	Rose. Eye color translucent pink.
507	35.5	eyg	Eye-gone. Eyes and head reduced.
508	36.2	gv	Grooved. Longitudinal medial groove in thorax.
509	36.5±	cr-3	Cream in 3. Specific dilutor of w^{a} eye color.
510	37±	rt	Rotated. Abdomen twisted counterclockwise.
511	37.5	app	Approximated. Crossveins close. Tarsi 4-jointed.
512	39±	pyd	Polychaetoid. Metra bristles.
513	39.7±	M(3)S37	Minute(3)Schultz'37. Extreme Minute.
514	40	tt	Tilt. Wings spread, warped, with gap in L3.
515	40.2	M(3)33j	Minute(3)33j. Medium Minute. Deficiency.
516	40.2	M(3)h	Minute(3)h. Medium Minute. Allele of M(3)33j.
517	40.2	M(3)y	Minute(3)y. Medium Minute. Allele of M(3)33j.
518	40.4±	vo-1	Vortex in 3. Intensifier of dp^{v}.
519	40.4±	D	Dichaete. Wings spread. Homozygous lethal.
520	40.5	Ly	Lyra. Wings cut, narrow. Homozygous lethal.
521	41.4	Gl	Glued. Eyes small, facets rounded. Homozygous lethal.
522	41.7±	fz	Frizzled. Thoracic hairs, bristles turn toward mid-line.
523	41.7±	rp	Rotated-penis. Male genitalia rotated. Male sterile.
524	42±	wk	Weak. Bristles weak, irregular. Body small.
525	43	Wi	Washed eye. Modifies w. Homozygous lethal.
526	43.2	th	Thread. Aristae threadlike, without branches.
527	43.4±	mh	Misnahar. Modifies B to larger eye.
528	43.5±	Cm	Crimp. Posterior wing edge crimped. Homozygous lethal.
529	43.6	hul	Bulge. Eyes bulging, wings squared off.
530	44±	M(3)S38	Minute(3)Schultz'38. Strong Minute.
531	44	st	Scarlet. Eye color scarlet, ocelli white.
532	45±	tra	Transformed. Transforms females to normal-appearing males.
533	45.3	cp	Clipped. Wing margins clipped.
534	46	mot-28	Mottled-28. Eyes mottled with hrown.
535	46	W	Wrinkled. Wings incompletely unfolded, pebhled.
536	46±	ae	Aecute. Wings held downward.
537	46±	je	Jelly. Eye color dark pinkish.
538	46±	Fdr	Purpleoider. Intensifier of pd.
539	47	in	Inturned. Thoracic bristles directed toward mid-line.
540	47±	M(3)S39	Minute(3)Schultz'39. Strong Minute.
541	47±	dn	Doughnut. Eye of se dn with light central spot. Male sterile.
542	47.1	ri	Radius incompletus. Vein L2 shows gap.
543	47.3	eg	Eagle. Wings spread, raised.
544	47.5	Dfd	Deformed. Eyes small. Homozygous lethal.
545	47.5	wp	Warped. Wings spread, douhly warped.

84. LINKAGE GROUPS: VARIOUS ANIMALS (Concluded)

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus		Symbol	Mutation and Phenotype
Fruit fly (Drosophila melanogaster) (continued)			
Chromosome III (Elements D and E) (continued)			
546	47.7	pb	Proboscipedia. Mouth parts footlike. Adult lethal.
547	48	p	Pink. Eye color dull ruby.
548	48±	Bb	Bubble. Wings small, inflated. Male sterile. Homozygous female lethal.
549	48.3	bod	Bowed. Wings arched.
550	48.5	tet	Tetraltera. Wings haltere-like.
551	48.7	by	Blistery. Wings blistered distally.
552	49±	M(3)S34	Minute(3)Schultz'34. Slight Minute.
553	49.7	ma	Maroon. Eye color dull ruby.
554	50	cu	Curled. Wings upcurved, body dark, postscutellars crossed.
555	50	M(3)S31	Minute(3)Schultz'31. Medium Minute. Deficiency.
556	50±	mu	Mussed. Wings thin, crumpled.
557	51±	ry	Rosy. Eye color deep ruby.
558	52	kar	Karmoisin. Eye color like st but duller. Ocelli colorless.
559	55±	C3G	Crossover suppressor in 3 of Gowen. Eliminates crossing over.
560	55.5±	red	Red. Red malpighian tubules.
561	56.7	jvl	Javelin-like. Bristles cylindrical, crooked.
562	57.9	cv-c	Crossveinless-c. Posterior crossvein absent or reduced.
563	58.2	Sb	Stubble. Bristles short, thick. Homozygous lethal.
564	58.5	ss	Spineless. Bristles very small.
565	58.8	bx	Bithorax. Balancers wing-like. Metathorax resembles mesothorax.
566	59.5±	cal	Coal. Black body color, similar to e^4.
567	59±	Rf	Roof. Wings drooping at sides.
568	59.9	fl	Fluted. Wings creased, darkish.
569	62	sr	Stripe. Dark dorsal stripe.
570	62.4	M(3)f	Minute(3)f. Minute type.
571	63.1	gl	Glass. Eye color dilute. Facets fused.
572	64±	gl-1	Glass-like. Eye color orange, eyes rough, small.
573	64±	k	Kidney. Eyes kidney shaped.
574	64±	M(3)S35	Minute(3)Schultz'35. Extreme Minute.
575	64.5±	sed	Sepiaoid. Eye color chocolate.
576	65±	cv-d	Crossveinless-d. Posterior crossvein absent or reduced.
577	66±	Cur	Curl. Curly wings. Homozygous lethal.
578	66.2	Dl	Delta. Veins thick at margin. Homozygous lethal.
579	69.5	H	Hairless. Some bristles and hair. Homozygous lethal.
580	70.7	e	Ebony. Body color black.
581	72.5	det	Detached. Crossveins broken, wings folded under.
582	75.7	cd	Cardinal. Eye color dull scarlet, ocelli white.
583	76.2	wo	White ocelli. Ocelli colorless.
584	77.5±	obt	Obtuse. Wings short, blunt.
585	79.1	bar-3	Bar-3. Phenotype like B/B.
Fruit fly (Drosophila melanogaster) (concluded)			
Chromosome III (Elements D and E) (concluded)			
586	79.7	M(3)124	Minute(3)124. Strong Minute. Allele of M(3)w.
587	79.7	M(3)B	Minute(3)Burkart. Moderate Minute. Allele of M(3)w.
588	79.7	$M(3)B^2$	Minute(3)Bridges. Strong Minute. Allele of M(3)w.
589	79.7	M(3)w	Minute(3)w. Strong Minute.
590	79.7	l(3)a	Lethal(3)first found. Lethal. Allele of M(3)w.
591	80±	M(3)Fla	Minute(3)Florida. Strong Minute. Allele of M(3)w.
592	84.5	M(3)36e	Minute(3)36e. Medium Minute.
593	87±	M(3)be	Minute(3)beta. Medium Minute.
594	88±	mah	Mahogany. Eye color brownish, darkening.
595	90	Pr	Prickly. Bristles vestiges. Homozygous semilethal.
596	90.2	m(3)j	Minute(3)j. Extreme Minute.
597	90.2	l(3)PR	Lethal with In(3R)P. Lethal. Allele of M(3)j.
598	91±	tx	Taxi. Wings divergent.
599	91.1	ro	Rough. Eyes rough, small.
600	91.8	l(3)XaR	Lethal(3)XaR. Balancer of T(2;3)Xa.
601	93±	cmp	Crumpled. Wings smaller, crumpled.
602	93.8	Bd	Beaded. Wing margins excised. Homozygous lethal.
603	94.1	Pw	Pointed-wing. Wings pointed at tip. Homozygous lethal.
604	95±	bf	Brief. Body small, bristles Minute-like. Male sterile.
605	95.4	rsd	Raised. Wings rise straight up.
606	95.5	su^B-pr	Suppressor of purple. Male sterile.
607	97.3	ra	Rase. Bristles, hairs smaller, fewer.
608	99.3±	Dp	Duplication. Similar to Ultra Bar.
609	100±	ld	Loboid. Eyes lobe-like.
610	100.7	ca	Claret. Eye color clear ruby.
611	101	M(3)l	Minute(3)l. Medium Minute.
612	104.3	bv	Brevis. Bristles short, stubby.
613	106.2	M(3)g	Minute(3)g. Slight Minute. Requires E-M(3)g.
Chromosome IV (Element F)			
614	0	ci	Cubitus-interruptus. Vein L4 interrupted.
615	0-0.2±	M-4	Minute-4. Medium Minute. Deficiency for ci, ar, gvl and Scn.
616	0-0.2	ar	Abdomen rotatum. Abdomen twisted clockwise.
617	0.2	gvl	Grooveless. Scutellar groove diminished.
618	1.4	bt	Bent. Wings bent, legs knobby.
619	2	ey	Eyeless. Eye small or absent.
620	3	sv	Shaven. Abdominal bristles fewer.

85. LINKAGE GROUPS: CORN AND TOMATO

Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus		Symbol	Phenotype [1]
Corn (Zea mays)			
Chromosome I			
1	0	sr	Striate leaves.
2	15	ga_6	Gametophyte viability factor.
3	21	zb_4	Zebra striping. Leaves with alternating transverse bands of green and whitish sectors.
Corn (Zea mays) (continued)			
Chromosome I (continued)			
4	25	ms_{17}	Male sterile.
5	27	ts_2	Tassel seed. Terminal inflorescence with pistillate flowers.
6	28	P	Pericarp color.

/1/ Certain of the phenotypes, e.g., virescent and tassel seed, occur more than once. Descriptions are given only for the first listing.

(continued, page 108)

Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Phenotype [1]
		Corn (Zea mays) (continued)
		Chromosome I (continued)
7	30	zl	Zygotic lethal.
8	53	as	Asynaptic. Chromosomes unpaired at meiosis.
9	66	hm	Helminthosporium susceptibility.
10	80	br	Brachytic. Stalk has short internodes.
11	84	Vg	Vestigial glumes.
12	85	f_1	Fine striped (green-white) leaves.
13	107	an_1	Anther ear. Stamens develop in pistillate inflorescence.
14	128	Kn	Knotted leaves. Wart-like growths on leaves and stalk.
15	134	gs_1	Green striped. Leaves with light green stripes between vascular bundles.
16	157	Tu_6	Tassel seed.
17	161	bm_2	Brown midrib. Brown pigment in midrib.
			Chromosome II
18	0	ws_3	White sheath. Leaf sheaths and stalk deficient in chlorophyll.
19	4	al	Albescent. Seedlings become whitish.
20	11	lg_1	Liguleless. Absence of ligule on leaves.
21	30	gl_2	Glossy seedling.
22	49	B	Anthocyanin booster.
23	56	sk	Sikless. Ears without silks.
24	68	fl_1	Floury endosperm.
25	74	ts_1	Tassel seed.
26	83	v_4	Virescent. Young seedlings deficient in chlorophyll.
27	128	Ch	Chocolate pericarp.
			Chromosome III
28	0	cr_1	Crinkly leaves.
29	18	d_1	Dwarf.
30	32	rt	Rootless.
31	38	Lg_3	Liguleless.
32	40	Rg	Ragged leaves. Leaves appear split and torn from development of necrotic areas.
33	47	ts_4	Tassel seed.
34	64	ba_1	Barren stalk. No ear produced.
35	75	na_1	Nana (dwarf).
36	103	a_1	Anthocyanin.
37	103-	sh_2	Shrunken endosperm.
38	115	et	Etched endosperm.
39	121	ga_7	Gametophyte factor.
			Chromosome IV
40	0	de_1	Defective endosperm.
41	35	Ga_1	Gametophyte factor.
42	56	Tu_5	Tassel seed.
43	66	sp_1	Small pollen.
44	71	su_1	Sugary endosperm.
45	74	de_{16}	Defective endosperm.
46	84	zb_6	Zebra striping.
47	100	Tu	Tunicate (pod corn). Enlarged glumes in male and female inflorescences.
48	105	J_2	Japonica striping. Leaves green-white striped.
49	111	gl_3	Glossy seedling.
			Chromosome V
50	0	gl_{17}	Glossy seedling.
51	1	a_2	Anthocyanin.
52	7	bm_1	Brown midrib.
53	8	bl_1	Brittle endosperm.
54	11	v_3	Virescent seedling.
55	13	bv	Brevis (dwarf) plant.
56	32	pr	Red aleurone color.
57	41	ys	Yellow stripe. Leaves green-yellow striped.
58	73	v_2	Virescent seedling.
			Chromosome VI
59	0	po	Polymitotic. Spores undergo extra meiotic-like divisions. Plants are male sterile.
60	13	Y	Yellow endosperm color.
61	33	pg_{11}	Pale green. Light green seedlings and plants.
62	44	Pl	Purple plant.
63	45	Bh	Blotched aleurone.
64	54	sm	Salmon silk.
65	64	py	Pigmy. Dwarf plant.
			Chromosome VII
66	0	o_2	Opaque endosperm.
67	4	in	Intensifier of aleurone color.
68	8	v_5	Virescent seedling.
69	22	ra_1	Ramosa. Branching of ear and tassel.
70	26	gl_1	Glossy seedling.
71	36	Tp	Torpod. Plant with many tillers and narrow leaves. Ears and tassels have enlarged bracts.
72	40	al	Slashed leaves.
73	42	lj	Lojap. Leaves green-white striped.

Locus	Symbol	Phenotype [1]
		Corn (Zea mays) (continued)
		Chromosome VII (concluded)
74	60	Bn	Brown endosperm color.
75	96	bd	Branched silkless. Ears branched without silks.
			Chromosome VIII
76	0	v_{16}	Virescent seedling.
77	14	ms_8	Male sterile.
78	28	j_1	Japonica striping.
			Chromosome IX
79	0	Dt	Dotted (controller of a_1 mutability).
80	7	yR_2	Yellow-green. Seedlings and plants of yellow-green color.
81	26	C	Aleurone color.
82	29	sh_1	Shrunken endosperm.
83	31	bz	Bronze aleurone and plant color.
84	44	bp	Brown pericarp color.
85	59	wx	Waxy endosperm.
86	66	pg_{12}	Pale green.
87	71	v_1	Virescent seedling.
88	74	bk_2	Brittle stalk.
89	106	Wc	White cap of endosperm.
			Chromosome X
90	0	Rp	Resistance to Puccinia.
91	16	Og	Old gold striping. Leaves green-yellow striped.
92	28	li	Lineate. Leaves with fine longitudinal striations.
93	38	l_6	Lutous seedling. Yellow seedlings.
			Tomato (Lycopersicon esculentum) [2]
			Chromosome 1 (Linkage Group III)
94	0	hr	Brachytic.
95	30	y	Colorless fruit skin.
96	65	Cf_1	Resistance to Cladosporium.
			Chromosome 2 (Linkage Group I)
97	0	dv	Dwarf virescent.
98	6	m	Mottled leaves.
99	11	d	Dwarf plant.
100	14	p	Peach
101	22	ro	Rosette.
102	25	ps	Positional sterile.
103	30	O	Oval fruit.
104	32	aw	Without anthocyanin.
105	48	Wo	Wooly plant.
106	53	s	Compound inflorescence.
107	60	ne	Necrotic leaves.
108	61	bk	Beaked fruits.
109	77	lc	Few fruit loculi.
			Chromosome 7 (Linkage Groups X and XII)
110	0	wt	Wilty foliage.
111	30	n	Nipple-tipped fruit.
			Chromosome 8 (Linkage Groups VI and VIII)
112	0	al	Anthocyanin absent.
113	40	dl	Dialytic stamens.
114	49	bu	Bushy.
115	76	l	Lutescent foliage.
			Chromosome 9
116	0	wd	Wilty dwarf.
			Chromosome 10 (Linkage Group VII)
117	0a	pe	Sticky fruit epidermis.
118	8	lg	Light green foliage.
119	36	u	Uniform-ripening fruit.
120	60	H	Hairs absent.
121	75	t	Tangerine fruit color.
122	98	Xa	Xantha seedling.
			Linkage Group II
123	0	r	Yellow fruit flesh.
124	15	wf	White flower.
			Linkage Group IV
125	0	c	Potato leaf.
126	17	sp	Self-pruning (determinate habit).
127	43	Cf_2	Cladosporium resistance.
			Linkage Group V
128	0	bi	Bifurcate inflorescence.
129	4	f	Fasciated fruit.
130	29	a	Anthocyanin absent.
131	49	hl	Hairless.
132	69	j	Jointless (also leafy inflorescence).
133	86	Cf_3	Cladosporium resistance.
			Linkage Group XI
134	0	e	Entire leaves.
135	28	w_1	Wiry foliage.
			Linkage Group IX
136	0	dm	Dwarf modifier.
			Unnumbered Linkage Group
137	0	tf	Trifoliate.
138	11	Fw	Furrowed cotyledons.

[1] Certain of the phenotypes, e.g., virescent and tassel seed, occur more than once. Descriptions are given only for the first listing. [2] Chromosome numbers are based on the identification of pachytene chromosomes according to length and, for this reason, certain chromosomes embrace more than one linkage group and do not always correspond to the linkage group numbers.

Part I: HYBRIDS REPORTED: PLANT AND ANIMAL KINGDOM

	Plants	Number		Animals	Number		Animals (concluded)	Number
1	Thallophytes	55	5	Echinoderms	30	9	Amphibia	52
2	Bryophytes	6	6	Molluscs	2	10	Reptiles	37
3	Pteridophytes	158	7	Arthropods	240	11	Birds	400
4	Spermatophytes	8946[1]	8	Fish	154	12	Mammals	300

/1/ Exclusive of the orchids.

Part II: MAMMALS AND BIRDS

	Parental Species		Sex Ratio	Hybrid Fertility	
	Female	Male	% Males[1]	Male	Female
		Mammals			
1	Bison, American (Bison bison)	Cattle, bull (Bos taurus)	31	Infertile	Fertile
2	Cattle, Brahma [Zebu] (B. taurus [indicus])	Gayal, Indian (Bibos frontalis)		Infertile	Fertile
3	Cattle, cow (B. taurus)	Bison, American (Bos americanus)	15.7	Infertile	Fertile
4	Cattle, cow (B. taurus)	Yak (B. grunniens)	36	Infertile[2]	Fertile
5	Guinea pig (Cavia porcellus)	Guinea pig, Peruvian (Cavia cutieri)		Fertile	Fertile
6	Horse (Equus caballus)	Ass [donkey] (Equus asinus)	44.4	Infertile	Fertile[3]
7	Horse (E. caballus)	Zebra (E. grevyi)		Infertile	Infertile
8	Mouse, Asiatic (Mus bactrianus)	Mouse, house (Mus musculus)	48.3	Fertile	Fertile
9	Mouse, house (M. musculus)	Mouse, Asiatic (M. bactrianus)	50.7	Fertile	Fertile
10	Yak (Bos grunniens)	Cattle, bull (Bos taurus)		Infertile[2]	Fertile
		Birds			
11	Chicken (Gallus domesticus)	Guinea fowl (Numida meleagris)		Infertile	
12	Chicken (G. domesticus)	Pheasant, common (Phasianus colchicus)	99.1	Infertile	
13	Chicken (G. domesticus)	Pheasant, ring-neck (P. torquatus)	88.5	Infertile	
14	Dove, dwarf turtle (Streptopelia humilis)	Dove, ring (Streptopelia risoria)	50	Fertile	Infertile
15	Dove, European turtle (S. turtur)	Dove, oriental turtle (S. orientalis)		Fertile	?
16	Dove, Oriental turtle (S. orientalis)	Dove, European turtle (S. turtur)		Fertile	Fertile
17	Dove, Oriental turtle (S. orientalis)	Dove, ring (S. risoria)	58.1	Fertile[4]	Fertile[4]
18	Dove, Oriental turtle (S. orientalis)	Pigeon, common (Columba livia)		Fertile[5]	?
19	Dove, ring (S. risoria)	Dove, dwarf turtle (Streptopelia humilis)	45.4	Fertile	Fertile
20	Dove, ring (S. risoria)	Dove, European turtle (S. turtur)	48.8	Fertile[4]	Fertile[4]
21	Dove, ring (S. risoria)	Dove, mourning (Zenaidura carolinensis)	100	Infertile	
22	Dove, ring (S. risoria)	Dove, pearl neck (Streptopelia chinensis)	57.8	Fertile	Fertile[4]
23	Dove, ring (S. risoria)	Dove, Senegal (S. senegalensis)	50	Fertile[4]	Fertile[4]
24	Dove, ring (S. risoria)	Pigeon, common (Columba livia)	97.2	Fertile[3]	Infertile
25	Dove, ring (S. risoria)	Pigeon, passenger (Ectopistes migratorius)		Infertile[5]	
26	Duck, mallard (Anas platyrhynchos)	Duck, dusky (Anas fulvigula)	54.8	Fertile	Fertile
27	Duck, mallard (A. platyrhynchos)	Duck, muscovy (Cairina moschata)	56.1	Infertile	Infertile
28	Duck, muscovy (Cairina moschata)	Duck, mallard (Anas platyrhynchos)	54.6	Infertile	Infertile
29	Grouse, European wood (Tetrao urogallus)	Grouse, European black (Lyrurus tetrix)	83.3	Fertile[5]	Fertile[5]
30	Pheasant, golden (Chrysolophus pictus)	Pheasant, Lady Amherst's (Chrysolophus amherstiae)	43.9	Fertile	Fertile
31	Pheasant, Reeves (Phasianus reevesi)	Pheasant, ring-neck (Phasianus torquatus)	91.7	Infertile	Infertile
32	Pheasant, ring-neck (P. torquatus)	Chicken (Gallus domesticus)	49.7	Infertile	Infertile
33	Pigeon, common (Columba livia)	Pigeon, Eurasian collared dove (Columba oenas)		Fertile	Fertile
34	Pigeon, common (C. livia)	Pigeon, triangular spotted (C. guinea)		Fertile[5]	Fertile[5]

/1/ Sex ratios are given only where the total number of hybrid offspring is a minimum of 25. Hybrid sex determined after hatching. /2/ Usually.
/3/ Rarely. /4/ Partially. /5/ Low.

Part III: INSECTS

	Parental Species		Sex Ratio	Hybrid Fertility	
	Female	Male	% Males[1]	Male	Female
	Moths and Butterflies				
1	Amorpha sustauti	Smerinthus atlanticus	90		
2	A. sustauti	S. ocellata	93		
3	A. populi	S. ocellata	98		
4	Clostera curtula	Clostera anachoreta		Fertile	Sterile
5	Deilephila galii	Chaerocampa elpenor >?1			
6	Lycia hirtaria	Nyssia zonaria	39.3	Fertile	Infertile
7	L. hirtaria	Poecilopsis pomonaria	75.6	Fertile	Infertile
8	Nyssia graecaria	Lycia hirtaria	100	Infertile	
9	N. zonaria	L. hirtaria	100	Infertile	
10	N. zonaria	Poecilopsis lapponaria	98.1		
11	N. zonaria	P. pomonaria	93.6		
12	Oporabia autumnata	Oporabia dilutata	52.5	Fertile	Infertile
13	Poecilopsis isabellae	Lycia hirtaria	54.3	Fertile	Infertile
14	P. lapponaria	Poecilopsis pomonaria	49.3	Fertile	Infertile
15	P. pomonaria	Lycia hirtaria	51.5	Fertile	Fertile
16	P. pomonaria	Nyssia zonaria	30.1		
17	Saturnia pyri	Saturnia pavonia	51.4	Fertile	Infertile
18	S. spini	S. pavonia	53	Fertile	Infertile
19	Smerinthus ocellata	Calasymbolus astylus	100		
20	Tephrosia bistortata	Tephrosia crepuscularia	96.9	Fertile	Fertile
21	T. crepuscularia	T. historitata	48.9	Fertile	Fertile

	Parental Species		Sex Ratio	Hybrid Fertility	
	Female	Male	% Males[1]	Male	Female
		Fruitflies			
22	Drosophila aldrichi	Drosophila aritonensis			Infertile
23	D. algonquin	D. athabasca		Infertile	Fertile
24	D. aritonensis	D. mojavensis		Infertile	Fertile
25	D. astecа	D. athabasca		Infertile	Infertile
26	D. melanogaster	D. simulans			Infertile
27	D. melanopalpa	D. neoreplesa		Fertile	Fertile
28	D. miranda	D. persimilis	50	Infertile	Fertile[2]
29	D. miranda	D. pseudoobscura	50	Infertile	Fertile[2]
30	D. mojavensis	D. aritonensis		Infertile	Fertile
31	D. montana	D. texana	90.9	Fertile	Infertile
32	D. mulleri	D. aldrichi		Infertile	Infertile
33	D. mulleri	D. aritonensis	100	Infertile	
34	D. mulleri	D. mojavensis			
35	D. munda	D. occidentalis	55.5	Fertile	Fertile
36	D. munda	D. subquinaria	49.6	Infertile	Infertile
37	D. pseudoobscura	D. miranda		Infertile	Fertile[2]
38	D. pseudoobscura	D. persimilis	48.2	Infertile	Fertile[2]
39	D. simulans	D. melanogaster		Infertile	Infertile
40	D. texana	D. montana	50.5	Fertile	Fertile
41	D. virilis	D. americana		Fertile	Fertile
42	D. virilis	D. montana	49.8	Fertile	Fertile

/1/ Sex ratios are given only where the total number of hybrid offspring is a minimum of 25. Hybrid sex determined after hatching. /2/ Rarely.

Part IV: PLANTS

SP = self pollination; CP = cross pollination; S = sterile; F = fertile; P = partially fertile; M = moderate.

	Parental Species	Compatibility			Parental Species	Compatibility	
		Parents	Hybrid			Parents	Hybrid
		Tomato (Lycopersicon species)					
1	L. esculentum x L. esculentum	SP- F; CP- F	SP- F; CP- F	9	L. glandulosum x L. peruvianum	CP- F	CP- S; CP- F
2	L. esculentum x L. glandulosum[1]	CP- S	SP- S; CP- P	10	L. glandulosum x L. pimpinellifolium[3]	CP- S	
3	L. esculentum x L. hirsutum	CP- F	SP- S; CP- P	11	L. hirsutum x L. hirsutum	SP- S	CP- S; CP- F
4	L. esculentum x L. h. glabratum	CP- F	SP- F; CP- F	12	L. hirsutum x L. pimpinellifolium	SP- F	SP- P; CP- F
5	L. esculentum x L. peruvianum[1,2]	CP- S	SP- S; CP- P	13	L. h. glabratum x L. h. glabratum	SP- F; CP- F	SP- F; CP- F
6	L. esculentum x L. pimpinellifolium	CP- F	SP- F; CP- F	14	L. peruvianum x L. peruvianum	SP- S; CP- F	SP- S; CP- F
7	L. esculentum x L. pissiai[1]	CP- S	SP- S; CP- P	15	L. peruvianum x L. pissiai	CP- S	
8	L. glandulosum x L. glandulosum	SP- S; CP- F	SP- S; CP- F	16	L. pimpinellifolium x L. pimpinellifolium	SP- F; CP- F	SP- F; CP- F

/1/ Hybrids obtainable from embryo culture, occasionally without. /2/ L. peruvianum var. dentatum (L. chilense) will cross with L. esculentum without embryo culture and the F_1 will hackcross more readily than other varieties of L. peruvianum. /3/ Hybrids probably obtainable with embryo culture.

FERTILITY AND INFERTILITY: HYBRIDS (Concluded)

Part IV: PLANTS (Concluded)

SP = self pollination; CP = cross pollination; S = sterile; F = fertile; P = partially fertile; M = moderate.

	Parental Species	Compatibility			Parental Species	Compatibility	
		Parents	Hybrid			Parents	Hybrid
	Pepper (Capsicum species)						
17	C. annum x C. annum	SP-F; CP-F	SP-F; CP-F	27	C. frutescens x C. pubescens	SP-S	
18	C. annum x C. pubescens	CP-S		28	C. frutescens x C. pendulum	SP-F	SP-S; CP-MS
19	C. annum x C. frutescens	CP-F[4]	SP-MS; CP-MS	29	C. pendulum x C. pendulum	SP-F; CP-F	SP-F; CP-F
20	C. annum x C. pendulum	CP-F[5]	SP-S; CP-S	30	C. pendulum x C. pubescens	CP-S	
21	C. annum x C. chacoense	CP-F	SP-S; CP-S	31	C. pubescens x C. pubescens	SP-F; CP-F	SP-F; CP-F
22	C. chacoense x C. chacoense	SP-F; CP-F	SP-F; CP-F	32	C. sinensis x C. annum	CP-F	SP-MS; CP-MS
23	C. chacoense x C. pubescens	CP-S		33	C. sinensis x C. frutescens	CP-F	SP-MS; CP-MS
24	C. chacoense x C. frutescens	CP-F	SP-S; CP-S	34	C. sinensis x C. pendulum	CP-F	SP-S; CP-S
25	C. chacoense x C. pendulum	CP-S[4]	SP-MS; CP-MS	35	C. sinensis x C. pubescens	CP-F[5]	SP-S; CP-S
26	C. frutescens x C. frutescens	SP-F; CP-F	SP-F; CP-F	36	C. sinensis x C. chacoense	CP-F[4]	SP-S; CP-MS
	Citrus species[6]						
37	C. aurantifolia x C. aurantifolia	SP-F; CP-F		51	C. limonia x C. reticulata	CP-F	
38	C. aurantifolia x C. limonia	CP-F		52	C. limonia x P. trifoliata	CP-F	
39	C. aurantifolia x Fortunella japonica	CP-F	CP-F	53	C. limonia x C. paradisi	CP-F	
40	C. aurantium x C. aurantium	SP-F; CP-F		54	C. paradisi x C. paradisi	SP-F; CP-F	
41	C. aurantium x Poncirus trifoliata	CP-F		55	C. paradisi x C. reticulata	CP-F	SP-S; CP-F
42	C. grandis x C. grandis	SP-F; CP-F		56	C. paradisi x C. sinensis	CP-F	
43	C. grandis x C. aurantium	CP-F		57	C. reticulata x C. reticulata	CP-F[7]	CP-F
44	C. grandis x C. reticulata	CP-F		58	C. reticulata x F. japonica	CP-F	
45	C. grandis x C. medica	CP-F		59	C. reticulata x P. trifoliata	CP-F	CP-F
46	C. grandis x C. sinensis	CP-F		60	C. reticulata x C. sinensis	CP-F	CP-F
47	C. grandis x C. paradisi	CP-F		61	C. reticulata x C. ichangensis	CP-F	
48	C. ichangensis x Poncirus trifoliata	CP-F		62	C. sinensis x C. sinensis	SP-F; CP-F	
49	C. limonia x C. limonia	SP-F; CP-F		63	C. sinensis x P. trifoliata	CP-F	SP-F[8]; CP-F
50	C. limonia x C. sinensis	CP-F		64	F. japonica x P. trifoliata	CP-F	

/4/ Slightly. /5/ With embryo culture. /6/ Lime (Citrus aurantifolia), orange (C. aurantium), grapefruit (C. grandis), Citrus sp (C. ichangensis), lemon (C. limonia), citron (C. medica), grapefruit (C. paradisi), orange (C. reticulata), orange (C. sinensis), kumquat (Fortunella japonica), trifoliate orange (Poncitrus trifoliata). /7/ A few varieties are self and cross incompatible. /8/ Some.

87. HYBRID VIGOR: CORN

Values in parentheses are estimates "bi" of the 95% range (cf Introduction).

Part I: COMPARATIVE GROWTH RATES IN RECIPROCAL CROSS: ENDOSPERM AND EMBRYO

	Days after Pollination	Dent[1]		Dent x Pop		Pop x Dent		Pop	
		Endosperm	Embryo	Endosperm	Embryo	Endosperm	Embryo	Endosperm	Embryo
1	12	0.2817	0.004	0.3684	0.006	0.245	0.001	0.215	0.001
2	16	1.0449	0.043	1.0668	0.049	0.585	0.020	0.556	0.012
3	20	2.0829	0.457	2.639	0.240	1.375	0.105	1.323	0.084
4	24	3.7549	0.493	3.938	0.556	1.915	0.221	1.904	0.153
5	28	5.1712	0.938	5.536	0.915	2.427	0.333	2.451	0.250
6	32	5.3761	1.081	5.997	1.074	3.089	0.449	2.894	0.315
7	36	5.6709	1.124	6.243	1.214	3.417	0.531	2.963	0.326
8	40	6.5997	1.541	7.438	1.409	3.662	0.566	3.343	0.395
9	44	7.0252	1.646	8.408	1.734	3.888	0.613	3.674	0.459
10	48	6.7793	1.702	8.541	1.724	4.341	0.705	3.398	0.483
11	52	7.3842	2.016	9.580	2.114	4.117	0.684	3.594	0.452
12	Harvest[2]	0.1805	0.0543	0.2171	0.0533	0.1059	0.0195	0.0925	0.0132

/1/ Individual harvest weights based on 50 kernel samples. /2/ Date and weight, linear component.

Part II: EFFECT OF CONTINUED INBREEDING ON REDUCTIONS IN HEIGHT AND YIELD. THREE INBRED LINES

	Generations, Number Inbred	Line 1-6		Line 1-7		Line 1-9	
		Height in.	Yield/Acre, bushels	Height in.	Yield/Acre, bushels	Height in.	Yield/Acre bushels
1	0	117	81(74-88)	117	81(74-88)	117	81(74-88)
2	1-5	87	64(53-75)	81	51(44-58)	77	41(36-46)
3	6-10	97(96-98)	45(33-57)	84(83-85)	36(31-41)	82(80-84)	34(30-38)
4	11-15	97(94-100)	38(34-42)	84(82-86)	34(31-37)	83(81-85)	26(24-28)
5	16-20	88(86-92)	22(18-26)	85(82-88)	24(21-27)	75(71-79)	14(11-17)
6	21-25	81(79-83)	20(14-26)	75(72-78)	21(18-24)	71(68-74)	13(11-15)
7	26-30	92(89-95)	24(15-33)	80(78-82)	18(14-22)	77(74-80)	9(5-13)

Part III: RELATIVE AVERAGE YIELDS. INBRED LINES AND DIALLEL F_1 CROSSES[3]

	Varieties	F_1 Hybrids[2]	Inbred		Varieties	F_1 Hybrids[2]	Inbred		Varieties	F_1 Hybrids[2]	Inbred
1	B2	87.4(81.4-93.4)	39.0(35.8-42.2)	4	OkO7	83.9(77.9-89.9)	28.5(25.3-31.7)	8	Hy	75.5(69.7-81.7)	31.9(28.7-35.1)
2	38-11	86.5(80.5-92.5)	26.5(23.3-29.7)	5	WF9	81.6(75.6-87.6)	28.5(25.3-31.7)	9	WV7	73.5(67.5-79.5)	20.1(16.9-23.3)
3	K159	86.3(80.3-92.3)	49.8(46.6-53.0)	6	B46	80.3(74.3-86.3)	39.8(36.6-43.0)	10	C.I.14	68.1(62.1-74.1)	2.7(0-5.9)
				7	OkO4	75.7(69.7-81.7)	15.1(11.9-18.3)				

/1/ Values, bushels/acre. /2/ All possible.

Part IV: DECREASE IN YIELDING CAPACITY. ADVANCED HYBRID GENERATIONS

	Specification	Average Yield, bushels/acre		Average Difference, F_1-P_1	Yield F_2, bushels/acre		Loss of Vigor, Grain Yield			
		F_1	P_1		Actual	Expected	Actual		Expected	
							bushels	%	bushels	%
1	10 single hybrids	62.8	23.74	39.06	44.2	43.3	18.6	47.6	19.5	50.0
2	4 three-way hybrids	64.2	23.75	40.45	49.3	50.7	14.9	36.8	13.5	33.3
3	10 double hybrids	64.1	25.00	39.10	54.0	54.3	10.1	25.8	9.8	25.0

Part V: EFFECT ON YIELD AND PLANT HEIGHT: VARIOUS LEVELS OF HETEROZYGOSITY

	Degree of Heterozygosity, %	Type of Combination	Number of Entries	Grain Yield, bushels/acre		Ear Node, Height, in.	
				Actual	Predicted[3]	Actual	Predicted
1	0	Inbred lines sibbed	4	41.5(40.57-42.43)		25.5(24.86-26.14)	
2	50	F_2 single crosses	6	62.2(60.18-64.22)	63.2(61.94-64.46)	32.8(32.08-33.52)	33.0(32.59-33.41)
3		Backcrosses	12	67.9(65.42-70.38)	63.2(61.94-64.46)	32.8(31.90-33.10)	33.0(32.59-33.41)
4	75	(A x B) (A x C)	12	75.2(73.14-77.26)	74.1(72.61-75.59)	38.4(37.62-39.18)	36.1(35.71-36.49)[1]
5	100	Single crosses	6	84.9(82.55-87.25)		39.6(39.06-40.14)	
6		Three-way crosses	12	84.9(82.46-87.34)	84.9(82.55-87.25)	40.5(39.90-41.10)	39.6(39.06-40.14)[1]
7		Double crosses	3	81.9(80.37-83.43)	84.9(82.55-87.25)[1]	40.9(40.01-41.79)	39.6(39.06-40.14)[1]

/1/ Differs significantly from actual.

88. HERITABILITY ESTIMATES: FARM ANIMALS

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part I: CHICKENS AND TURKEYS

	Characteristic	Method of Estimation[1] h^2S	h^2D	h^2DS	$h^2o.d.$
	Chickens[2]				
1	Body weight, 8 wk (NH)	(16-39)		(32-50)	45
2	Body weight, 8 wk (BPR)	(31-32)		(33-60)	39
3	Body weight, 8 wk (Composite)			46	40
4	Body weight, 10 wk (W. Wyan.)		(20-63)		
5	Body weight, 10 wk (Composite)			46	33
6	Body weight, 12 wk (SCWL)	20			
7	Body weight, 12 wk (NH)	42	60	51	
8	Body weight, 22 wk (WL)	27			
9	Body depth (NH)	11		43	
10	Keel length (NH)	(27-50)	17	(34-37)	
11	Breast width (NH)	13	29	21	
12	Shank length (NH)	50	48	(33-49)	
13	Shank length (WL)			(33-54)	
14	Thyroid weight (NH)			48	
15	Testes weight (NH)			29	
16	Feathering, 8 wk (NH)			33	
17	Feathering, 8 wk (BPR)			42	
18	Egg production[3] (WL)	21	22	(15-22)	(9-16)
19	Egg production[3] (BPR)		41	25	30
20	Rate, Dec. to Mar. (Composite)			41	11
21	Rate, Mar. to June (Composite)			38	0
22	Rate, Dec. to June (Composite)			51	0
23	Production Index (WL)	23	10	16	57
24	Sexual maturity (WL)	(24-27)	17	(31-33)	(31-35)
25	Sexual maturity (Composite)			20	(7-26)
26	Pause, 6 da (Composite)			(16-20)	(21-23)
27	Pause, winter (WL)	8[4]			73
28	Persistency (Composite)			10	
29	Persistency (WL)	5[4]			
30	Total mortality[5] (Composite)			12	
31	Total mortality[5] (WL)	8	11	8	
32	Leukosis mortality (WL)	5	3	8	
33	Reproductive disorders (WL)	2	6		
34	Hatchability (Composite) Egg weight[7]				16
35	Sexual maturity[8] (WL)	60		50	(44-61)
36	Nov. (10 eggs) (WL)	48		36	61
37	March (1 egg) (Composite)			52	52
38	April (10 eggs) (WL)			47	39
39	April (10 eggs) (Composite)				61
40	Jan. to May[9] (WL)	37[4]			55
41	Dec. to May[10] (NH)			67	
42	Dec. to May[10] (BPR)			40	
43	Dec. to May[10] (WL)			93	
44	Dec. to May[10] (Composite)				50
45	Shell color (BPR; RIR)	30	91	58	78
46	Albumin weight (NH)			83	
47	Albumin weight (BPR)			14	

	Characteristic	Method of Estimation[1] h^2S	h^2D	$h^2o.d.$
	Chickens (concluded)[2]			
48	Albumin weight (WL)		110	
49	Albumin weight (Composite)		22	
50	Yolk weight (NH)		0	
51	Yolk weight (BPR)		2	
52	Yolk weight (WL)		20	
53	Shell texture (Composite)		27	
54	Shell thickness (Composite)		27	
55	Blood spots (WL)		67	46
	Turkeys[2]			
56	Body weight, 2 wk (MW)	♂28013	♂69073	
57	Body weight, 4 wk (MW)	♂4	♂37076	♂20238
58	Body weight, 4 wk (BBB)	♂49338		♂40044
59	Body weight, 4 wk (BSW)			♂26019
60	Body weight, 8 wk (MW)	♂19632	♂21072	♂20238
61	Body weight, 8 wk (BBB)	♂56628		♂45945
62	Body weight, 8 wk (BSW)	♂1108		♂33016
63	Body weight, 14 wk (BBB)	♂72239		♂62029
64	Body weight, 14 wk (BSW)	♂6818		♂19016
65	Body weight 16 wk (MW)	♂46021	♂27067	♂36944
66	Body weight, 16 wk (WH)	♂23059	♂62042	♂42050	♂62041
67	Body weight, 24 wk (MW)	♂38029	♂1202	♂25016
68	Body weight, 24 wk (WH)	♂33061	♂68070	♂51060	♂68059
69	Body weight, 25 wk (BBB)	♂34029	♂2271	♂18050
70	Body weight, 25 wk (WH)	♂29024	♂71071	♂50047
71	Body weight, 26 wk (BBB)	♂52029		♂52025
72	Body weight, 26 wk (BSW)	♂13019		♂20024
73	Breast width, 26 wk (BBB)	♂494		♂23013
74	Breast width, 26 wk (BSW)			♂37040
75	Breast depth, 26 wk (BBB)	♂22021		♂30040
76	Breast depth, 26 wk (BSW)			♂41021
77	Keel length, 26 wk (BBB)	♂32015		♂22018
78	Keel length, 26 wk (BSW)			♂-5014
79	Shank length, 26 wk (BBB)	♂25		♂34
80	Shank length, 26 wk (BSW)			♂52
81	Egg production, Feb-June (B)				92
82	Egg production, Feb-June (BSW)				911
83	Egg production, Feb-June (BBB)	♀9		♀14	♀16
84	Egg production, Feb-June (WH)	♀29	♀27	♀28
85	Egg weight, Feb. (10 eggs) (BBB)	♀53		♀50	♀64
86	Egg weight, May (10 eggs) (WH)	♀22	♀62	♀42
87	Fertility, 1-7 da [11] (BBB)		♀53	♀26
88	Fertility, 8-14 da [11] (BBB)		♀26	♀12
89	Fertility (BBB)			♀30
90	Hatchability, 1-7 da (BBB)	♀3		♀13	♀40
91	Hatchability, 8-14 da (BBB)	♀14		♀21	♀26
92	Hatchability, Feb-June (B)				♀33
93	Hatchability, Feb-June (BSW)				♀1

/1/ h^2S = paternal half sib correlation; h^2D = maternal half sib correlation; h^2DS = full sib correlation; $h^2o.d.$ = offspring-dam regression. /2/ Breeds and varieties are denoted in parentheses. For chickens: NH = New Hampshire, BPR = Barred Plymouth Rock, WL = White Leghorn, SCWL = Single Comb White Leghorn, W. Wyan. = White Wyandotte, RIR = Rhode Island Red. Composite = composite of several breeds. For turkeys: MW = Medium White, BBB = Broad Breasted Bronze, B = Bronze, BSW = Beltsville Small White, WH = White Holland. /3/ Annual egg production of survivors. /4/ Method of determining estimate not specified. /5/ 319 da after housing. /6/ 1st laying year. /7/ Estimates based on cited number of eggs at specified periods. /8/ 10 eggs. /9/ All eggs. /10/ Representative egg sample. /11/ Stored eggs.

Part II: BEEF AND DAIRY CATTLE

	Characteristic	Method of Estimation[1] P	DO	SO	S
	Beef Cattle[2]				
1	Birth weight	48	42	35	
2	Gain, birth to weaning	21	7	17	
3	Weaning weight	28	10	26	
4	Yearling weight, off pasture	45	39		
5	Gain, off pasture	39	18		30
6	Final feedlot weight	84		92	
7	Gain in feedlot	64		97	43
8	Grade or score at weaning	27	22	11	
9	Grade or score as yearlings[3]	27	14		
10	Grade or score at slaughter	46			
11	Carcass grade	32			
12	Economy of gain	29		48	

	Characteristic	Method of Estimation h^2
	Dairy Cattle	
13	Birth weight	60[5]
14	Mature weight	60[5]
15	Milk production	(25-38)
16	Butterfat production	(17-32)
17	Butterfat per cent	(33-57)
18	Type classification rating (overall)	(14-31)
19	Amount of spotting (Holsteins)	(93-99)
20	Mastitis resistance	(14-38)
21	Gestation length	32[5]
22	Services per conception	(3-7)

/1/ P = paternal half sibs, DO = dam offspring regression, SO = sire offspring regression, S = selection experiments. /2/ Values prepresent weighted averages (based on volume of data) of published estimates. Not listed are area of eye muscle, 70F, and thickness of fat, 38F. /3/ Off pasture. /4/ Estimates based on intrasire regression unless otherwise noted. /5/ Average of several methods and/or breeds.

88. HERITABILITY ESTIMATES: FARM ANIMALS (Continued)

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part III: SHEEP

	Characteristic	Method of Estimation[1]		
		p	b	Average[2]
1	Birth weight	30		
2	Yearling staple length		36	
3	Yearling weight clean wool		(28-38)	
4	Yearling body weight		40	
5	Yearling body score		12	
6	Body folds		37	
7	Weaning weight	27		
8	Staple length at weaning	41	(34-39)	(17-43)

	Characteristic	Method of Estimation[1]		
		p	b	Average[2]
9	Type score at weaning	15	7	(7-13)
10	Condition score at weaning	2.4	14	(4-21)
11	Skin folds			(45-51)
12	Neck folds	36	45	(8-39)
13	Face covering	51	60	(46-56)
14	Number of nipples		14.4[3]	
15	Number of functional nipples		22	

/1/ p = paternal half sibs, b = intrasire regression. /2/ Average of several methods and/or breeds. /3/ Intrasire correlation.

Part IV: SWINE

	Characteristic	Breed	Estimate of Heritability[1]	
1	Birth weight	Composite	2	A
2	Birth weight	Duroc	0	B
3	Birth weight	Duroc	-23	E
4	Birth weight	Hampshire	5	A
5	Birth weight	Hampshire	6	D
6	Birth weight	Hampshire	8	E
7	Birth weight	Not stated	14	D
8	Body weight, 21 da	Duroc	4	A
9	Body weight, 21 da	Hampshire	24	A
10	Body weight, 21 da	Hampshire	14	D
11	Body weight, 21 da	Hampshire	-4	E
12	Body weight, 21 da	Not stated	-6	D
13	Body weight, 56 da	Duroc *	15	A
14	Body weight, 56 da	Hampshire	17	A
15	Body weight, 56 da	Hampshire	8	D
16	Body weight, 56 da	Hampshire	-2	E
17	Body weight, 56 da	P.C. and Landrace	3	D
18	Body weight, 56 da	P.C. and Minn. No. 1	-20	D
19	Body weight, 60 da	Poland China	7	A
20	Body weight, 63 da	Duroc	14	D
21	Body weight, 72 da	Duroc	9	E
22	Body weight, 84 da	Duroc	26	A
23	Body weight, 112 da	Duroc	28	A
24	Body weight, 112 da	Not stated	0	A
25	Body weight, 140 da	Duroc	19	A
26	Body weight, 140 da	Not stated	21	A
27	Body weight, 150 da	Hampshire	14	A
28	Body weight, 150 da	Hampshire	16	J
29	Body weight, 154 da	Not stated	10	D
30	Body weight, 154 da	P.C. and Landrace	7	D
31	Body weight, 154 da	Hampshire	23	D
32	Body weight, 154 da	Hampshire	17	J
33	Body weight, 154 da	Hampshire	9	E
34	Body weight, 154 da	Composite	19	P
35	Body weight, 168 da	Duroc	25	A
36	Body weight, 168 da	Not stated	27	A
37	Body weight, 180 da	Poland China	20	A
38	Body weight, 180 da	Poland China	62	D
39	Body weight, 180 da	Poland China	30	M
40	Body weight, 180 da	Poland China	40	I
41	Body weight, 180 da	Poland China	30	D
42	Body weight, 180 da	P.C. and Minn. No. 1	14	D
43	Body weight, 180 da	Duroc	22	D
44	Body weight, 180 da	Duroc	23	N
45	Body weight, 180 da	Hampshire	24	A
46	Body weight, 180 da	Hampshire	65	D
47	Body weight, 180 da	Hampshire	19	J
48	Body weight, 180 da	Hampshire	5	D
49	Body weight, 180 da	Hampshire	22	E
50	Body weight, 180 da	Hampshire	16	J
51	Body weight, 180 da	P.C. and Landrace	34	A
52	Body weight, 200 da	Yorkshire	27	G
	Body weight gain			
53	Birth-21 da	Duroc	7	A
54	Birth-56 da	Duroc	22	A
55	Birth-56 da	Duroc	15	A
56	Birth-56 da	Crosses	2	A
57	21-56 da	Duroc	15	A
58	21-56 da	Not stated	-2	D
59	56-84 da	Duroc	20	A
60	56-84 da	Not stated	18	A
61	56-84 da	Not stated	6	D
62	56-112 da	Duroc	51	A
63	56-112 da	Duroc	28	A
64	56-112 da	Crosses	35	A
65	56-112 da	Not stated	28	A

	Characteristic	Breed	Estimate of Heritability[1]	
66	56-168 da	Not stated	45	A
67	84-112 da	Not stated	10	D
68	84-112 da	Duroc	31	A
69	112-140 da	Duroc	4	A
70	112-140 da	Not stated	10	D
71	112-154 da	Duroc	25	A
72	112-154 da	Crosses	34	A
73	112-168 da	Duroc	17	A
74	140-168 da	Duroc	13	A
75	140-168	Not stated	10	D
	Daily weight gain			
76	Birth-200 lb	Not stated	21	A
77	Birth-200 lb	Not stated	3	D
78	56 da - 200 lb	P.C. and Minn. No. 1	31	D
79	56 da - 200 lb	Not stated	40	A
80	56 da - 200 lb	Not stated	21	D
81	56 da - 200 lb	Danish Landrace	41	A
82	56 da - 200 lb	Danish Landrace	46	B
83	56 da - 200 lb	Danish Landrace	-19	F
84	56 da - 200 lb	Danish Landrace	24	O
85	56 da - 225 lb	Duroc	18	A
86	56 da - 225 lb	P.C. and Landrace	31	A
87	56 da - 112 da	Duroc	18	A
88	72 da - 225 lb	Duroc	43	E
89	112 da - 225 lb	Duroc	14	A
90	50 lb - 200 lb	P.C. and Minn. No. 1	26	D
	Sow Productivity			
91	Litter size at birth	Composite	17	K
92	Litter size at birth	Poland China	17	H
93	Litter size at birth	Poland China	18	H
94	Litter size at birth	Yorkshire	10	H
95	Litter size at birth	Tamworth	34	H
96	Litter size at birth	Berkshire	44	H
97	Litter size at birth	Chester White	13	K
98	Litter size at birth	P.C. and Landrace	-11	D
99	Litter size at birth	Duroc	25	D
100	Litter size at birth	Duroc	24	K
101	Litter size at birth	German Landrace	14	A
102	Litter size at birth	German grazing hog	12	A
103	Litter size at birth	Duroc	3	D
104	Litter size at birth	Composite	16	A
105	Litter size at birth	Composite	14	D
106	Litter size at birth	Composite	15	L
107	Litter size at birth	Not stated	7	D
108	Litter size at birth	Duroc	22	K
109	Litter size at birth	Duroc	28	K
110	Litter size at birth	Swiss Land. and York.	12	K
111	Live pigs farrowed	Composite	18	A
112	Live pigs farrowed	Composite	16	D
113	Live pigs farrowed	Composite	9	I
114	Live pigs farrowed	Duroc	24	D
115	Live pigs farrowed	Duroc	21	K
116	Live pigs farrowed	Composite	22	D
117	Litter size, 21 da	Duroc	20	D
118	Litter size, 21 da	Duroc	34	K
119	Litter size, 21 da	Swiss Land. and York.	7	K
120	Litter size, 28 da	Chester White	16	K
121	Litter size, 56 da	Not stated	6	D
122	Litter size, 56 da	Duroc	19	D
123	Litter size, 56 da	Duroc	25	K
124	Litter size, 56 da	P.C. and Landrace	-9	D
125	Litter size, 56 da	Duroc	13	K
126	Litter size, 56 da	Duroc	18	K
127	Litter size, 56 da	Composite	32	D
128	Percent live pigs, 56 da	Composite	40	D
129	Litter size, 56-70 da	Composite	17	K

/1/ Estimates of heritability are based on the indicated methods: A = paternal half sib correlation, B = maternal half sib correlation, C = paternal and maternal half sib correlations, D = intra-sire regression of progeny on dam, E = regression of progeny on mean of parents, F = correlation between progeny averages of sire and of son, G = regression of progeny on mean of parental full sibs, H = daughter-dam correlation, I = correlation between full sibs, J = line differences due to selection, K = repeatability of sow's own performance, L = variance between strains, M = regression of variance on genetic relationship between pigs, N = average of two methods, O = average of three methods, P = method not specified.

88. HERITABILITY ESTIMATES: FARM ANIMALS (Concluded)

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part IV: SWINE (Concluded)

	Characteristic	Breed	Estimate of Heritability[1]			Characteristic	Breed	Estimate of Heritability[1]	
130	Litter size, 63 da	Duroc	~3	D	180	Thickness of shoulder fat	Yorkshire	42	A
131	Litter size, 70 da	Chester White	20	K	181	Thickness of shoulder fat	Yorkshire	49	C
132	Litter size, 154 da	Not stated	9	D	182	Thickness of loin fat	Yorkshire	48	A
133	Litter size, 154 da	P.C. and Landrace	~15	D	183	Thickness of loin fat	Yorkshire	59	C
134	Litter size, 168 da	Duroc	42	D	184	Thickness of belly	Swedish Landrace	39	A
135	Litter size, 168 da	Duroc	32	K	185	Thickness of belly	Danish Landrace	62	A
136	Litter size, 180 da	Duroc	~12	D	186	Thickness of belly	Danish Landrace	44	B
137	Litter weight at birth	Composite	36	D	187	Thickness of belly	Danish Landrace	47	F
138	Litter weight, 21 da	Swiss Land. and York.	12	K	188	Thickness of belly	Danish Landrace	46	O
139	Litter weight, 56 da	Composite	7	D	189	Length of carcass	Yorkshire	40	A
140	Litter weight, 56 da	Duroc	21	D	190	Length of carcass	Yorkshire	60	C
141	Litter weight, 56 da	Duroc	53	K	191	Length of carcass	Yorkshire	42	G
142	Litter weight, 56 da	Not stated	2	D	192	Length of carcass	Composite	58	P
143	Litter weight at weaning	Duroc	14	K	193	Length of carcass	P.C. and Landrace	73	A
144	Litter weight at weaning	Duroc	0	K	194	Length of carcass	Swedish Landrace	61	A
145	Litter weight, 60 da	Composite	18	K	195	Length of carcass	Danish Landrace	78	A
146	Litter weight, 154 da	Not stated	11	D	196	Length of carcass	Danish Landrace	81	B
147	Litter weight, 168 da	Duroc	2	D	197	Length of carcass	Danish Landrace	35	F
148	Litter weight, 168 da	Duroc	34	K	198	Length of carcass	Danish Landrace	54	O
149	Productivity index	Poland China	16	D	199	Length of hind leg	Duroc	23	A
150	Length of gestation	P.C. and Landrace	21	I	200	Length of hind leg	Composite	73	P
151	Feed economy	P.C. and Landraca	57	A	201	Length of hind leg	P.C. and Landrace	58	A
152	Feed economy	Duroc	26	E	202	Per cent lean cuts	P.C. and Landrace	29	A
153	Feed economy	Duroc	24	J	203	Per cent lean cuts	Composite	15	P
154	Feed economy	Yorkshira	30	A	204	Per cent fat cuts	P.C. and Landrace	52	A
155	Feed economy	Yorkshire	57	C	205	Per cent fat cuts	Composite	69	P
156	Feed economy	Composite	26	P	206	Per cent ham	Yorkshire	51	A
157	Feed economy	Danish Landrace	29	A^2	207	Per cent ham	Yorkshire	65	C
158	Feed economy	Danish Landrace	12	B^2	208	Per cent shoulder	Yorkshire	38	A
159	Feed economy	Danish Landrace	~10	F^2	209	Per cent shoulder	Yorkshire	56	C
160	Feed economy	Danish Landrace	8	O^2	210	Per cent Wiltshire sides	Danish Landrace	40	A
161	Feed economy	Swedish Landrace	12	A	211	Per cent Wiltshire sides	Danish Landrace	32	B
162	Feed economy	Swedish Landrace	23	A	212	Per cent Wiltshire sides	Danish Landrace	0	F
163	Market score	Duroc	33	N	213	Per cent Wiltshire sides	Danish Landrace	20	O
164	Market score	Poland China	10	D	214	Size of ham	Swedish Landrace	61	A
165	Age at slaughter	Swedish Landrace	57	A	215	Ham circumference	Duroc	17	A
166	Age at 200 lb weight	Yorkshire	55	A	216	Loin area	Yorkshire	66	A
167	Age at 200 lb weight Carcass	Yorkshire	85	C	217	Loin area	Yorkshire	79	C
168	Dressing per cant	P.C. and Landrace	38	A	218	Loin area	Yorkshire	16	G
169	Thickness of backfat	P.C. and Landrace	54	A	219	Carcass score	Yorkshire	35	G
170	Thickness of backfat	Duroc	12	A	220	Carcass score	Yorkshire	35	A
171	Thickness of backfat	Composite	40	P	221	Carcass score	Yorkshire	49	C
172	Thickness of backfat	Landrace Danish	80	A	222	Belly score	Yorkshire	14	A
173	Thickness of backfat	Danish Landrace	55	B	223	Firmness of fat scora	Swedish Landraca	35	A
174	Thickness of backfat	Danish Landrace	37	F	224	Conformation score	Poland China	20	D
175	Thickness of backfat	Danish Landrace	47	O	225	Type score within strains	Poland China	38	A
176	Thickness of backfat	Swedish Landrace	54	A	226	Type score between strains	Poland China	92	L
177	Thickness of backfat	Yorkshire	37	G	227	Number of vertebrae	Composite	74	E
178	Thickness of backfat	Yorkshire	38	A	228	Scrotal hernia	P.C. and Landrace	15	A
179	Thickness of backfat	Yorkshire	53	C	229	Amount of spotting	Beltsville No. 1	76	O

/1/ Estimates of heritability are based on the indicated methods: A = paternal half sib correlation, B = maternal half sib correlation, C = paternal and maternal half sib correlations, D = intra-sire regression of progeny on dam, E = regression of progeny on mean of parents, F = correlation between progeny averages of sire and of son, G = regression of progeny on mean of parantal full sibs, H = daughter-dam correlation, I = correlation between full sibs, J = line differences due to selection, K = repeatability of sow's own performance, L = variance between strains, M = regression of variance on genetic relationship between pigs, N = average of two methods, O = average of three methods, P = method not specified.
/2/ To be multiplied by $(1 + 3r_{oo})$ where r_{oo} is the correlation between litter mates.

89. GENETIC SEGREGATIONS AT 1% AND 5% PROBABILITY LEVELS

Values are given for the number of offspring required in order to obtain at least one desired individual among different genetic segregations at 1% and 5% probability levels. Numbers underlined indicate that corresponding calculated numbers are between 0.01 and 0.49 greater than the number entered.

	Ratio of Undesired to Desired Type	Type of Segregation	Number[1] of Required Offspring — Probability Level 1%	5%
		F_2 Segregation		
1	2:1	Monohybrid, homozygous lethal	12	7
2	3:1	Any (normal) monohybrid	16	10
3	15:1	Any dihybrid	71	46
4	63:1	Any trihybrid	292	190
5	255:1	Any tetrahybrid	1177	765
		Backcross (Testcross) Segregations		
6	1:1	Any monohybrid	7	4
7	3:1	Any dihybrid	16	10
8	7:1	Any trihybrid	35	22
9	15:1	Any tetrahybrid	71	46
10	31:1	Any pentahybrid	145	94
		Genotypic Segregations		
11	2:1	Any class of 3, e.g., 9:3:3:1	12	7
12	5:1	Any class of 6, e.g., 9:6:1	25	16
13	6:1	Any class of 7, e.g., 9:7 or 7:1	30	19
14	8:1	Any class of 9, e.g., 9:3:3:1	39	25
15	11:1	Any class of 12, e.g., 12:3:1	53	34
16	14:1	Any class of 15, e.g., 15:1	67	43
17	26:1	Any class of 27, e.g., 27:37	122	79
18	36:1	Any class of 37, e.g., 27:37	168	109
19	62:1	Any class of 63, e.g., 63:1	288	187
20	80:1	Any class of 81, e.g., 81:175	371	241

Remarks

General method for calculating number (n) of required individuals at desired probability levels for all Mendelian ratios:

$$p = (\tfrac{f}{e})^n$$

p = probability level desired
e = the multiple dominant term of the numerator of a Mendelian fraction
f = the common denominator of all the terms of the Mendelian fraction
n = the number of required individuals needed to assure the desired probability level

Example: How many individuals in a 15:1 Mendelian ratio are required to show at 5% probability that oo double recessive is expected?

p = 0.05 e = 15 f = 16 n = ?

Solving by logarithms:

n(log 15 - log 16) = log 0.05

Answer: n = 46.4

Note: Rule of thumb method for estimating any value of n is: at 5% probability use three times the Mendelian denominator; at 1% probability use five times the Mendelian denominator.

/1/ Values are calculated from formula, $o = k(r + \frac{1}{2})$, where k equals 4.61 and 3.00 for the 1% and 5% probability levels, respectively; r equals the ratio between the undesired and desired types.

90. SIGNIFICANT LEVELS OF t, F, AND χ^2

In each cell upper value represents 5% level, lower value 1% level.

Degrees of freedom for lesser mean square	Degrees of freedom for greater mean square[1]													
	1	2	3	4	5	6	8	10	12	15	20	50
	t	F										
1	12.7 63.7	161 4052	200 4999	216 5403	225 5625	230 5764	234 5859	239 5981	242 6056	244 6106	246 6156	248 6208	252 6302
2	4.3 9.9	18.5 98.5	19.0 99.0	19.2 99.2	19.2 99.3	19.3 99.3	19.3 99.4	19.4 99.4	19.4 99.4	19.4 99.4	19.4 99.4	19.4 99.4	19.5 99.5
3	3.2 5.8	10.1 34.1	9.6 30.8	9.3 29.5	9.1 28.7	9.0 28.2	8.9 27.9	8.8 27.5	8.8 27.2	8.7 27.0	8.7 26.9	8.7 26.7	8.6 26.4
4	2.8 4.6	7.7 21.2	6.9 18.0	6.6 16.7	6.4 16.0	6.3 15.5	6.2 15.2	6.0 14.8	6.0 14.5	5.9 14.4	5.9 14.2	5.8 14.0	5.7 13.7
5	2.6 4.0	6.6 16.3	5.8 13.3	5.4 12.1	5.2 11.4	5.0 11.0	5.0 10.7	4.8 10.3	4.7 10.0	4.7 9.9	4.6 9.7	4.6 9.6	4.4 9.2
6	2.4 3.7	6.0 13.7	5.1 10.9	4.8 9.8	4.5 9.2	4.4 8.8	4.3 8.5	4.2 8.1	4.1 7.9	4.0 7.7	3.9 7.6	3.9 7.4	3.8 7.1
8	2.3 3.4	5.3 11.3	4.5 8.6	4.1 7.6	3.8 7.0	3.7 6.6	3.6 6.4	3.4 6.0	3.3 5.8	3.3 5.7	3.2 5.5	3.2 5.4	3.0 5.1
10	2.2 3.2	5.0 10.0	4.1 7.6	3.7 6.6	3.5 6.0	3.3 5.6	3.2 5.4	3.1 5.1	3.0 4.8	2.9 4.7	2.8 4.6	2.8 4.4	2.6 4.1
12	2.2 3.1	4.8 9.3	3.9 6.9	3.5 6.0	3.3 5.4	3.1 5.1	3.0 4.8	2.8 4.5	2.8 4.3	2.7 4.2	2.6 4.0	2.5 3.9	2.4 3.6
15	2.1 2.9	4.5 8.7	3.7 6.4	3.3 5.4	3.1 4.9	2.9 4.6	2.8 4.3	2.6 4.0	2.6 3.8	2.5 3.7	2.4 3.5	2.3 3.4	2.2 3.1
20	2.1 2.8	4.4 8.1	3.5 5.8	3.1 4.9	2.9 4.4	2.7 4.1	2.6 3.9	2.4 3.6	2.4 3.4	2.3 3.2	2.2 3.1	2.1 2.9	2.0 2.6
50	2.0 2.7	4.0 7.2	3.2 5.1	2.8 4.2	2.6 3.7	2.4 3.4	2.3 3.2	2.1 2.9	2.0 2.7	2.0 2.6	1.9 2.4	1.8 2.3	1.6 1.9
100	2.0 2.6	3.9 6.9	3.1 4.8	2.7 4.0	2.5 3.5	2.3 3.2	2.2 3.0	2.0 2.7	1.9 2.5	1.8 2.4	1.8 2.2	1.7 2.1	1.5 1.7
∞	1.96 2.58	3.8 6.6	3.0 4.6	2.6 3.8	2.4 3.3	2.2 3.0	2.1 2.8	1.9 2.5	1.8 2.3	1.8 2.2	1.7 2.0	1.6 1.9	1.4 1.5
χ^2=		3.8 6.6	6.0 9.2	7.8 11.3	9.5 13.3	11.1 15.1	12.6 16.8	15.5 20.1	18.3 23.2	21.0 26.2	25.0 30.6	31.4 37.6	67.5 76.0

/1/ With only one degree of freedom for greater mean square, $F = t^2$; and chi-square for n d.f. is equal to n x F, for n and oo d.f.

9L BREEDING HABITS: MAMMALS

If the estrous cycle occurs typically in a species as an isolated event during the breeding season, the species is monestrous, (Me). If the cycles occur in series, continuously, or seasonally, the species is polyestrous, (Pe). If a female mates with only one male during its lifetime, the female is monogamous, (Mo); if it mates with a different male each breeding season it is polygamous, (Po); and if it mates with 2 or more different males during any one breeding season it is promiscuous, (Pr). Values in parentheses are ranges, estimate "ó" of the 95% range (cf Introduction).

	Species	Age at Puberty	Breeding Season	Sexual Cycle Type	Sexual Cycle Duration, da	Gestation Period, da	Litter Size	Litter No./yr	Mating Habits
1	Man (Homo sapiens)	(12-15.4) yr	All yr	Pe	(27-28)	267[1]	1[2,1]		
2	Antelope (Hippotragus niger)		All yr			(270-281)			
3	Ape (Macaca sylvanus)			Pe	(27-33)	210			
4	Armadillo (Dasypus novemcinctus)	1 yr	Summer	Me		(150-240)	4	1	
5	Ass (Equus asinus)	1 yr	Mar-Aug	Pe	22	365(340-385	1		
6	Baboon (Papio porcarius)	4 yr	All yr	Pe	(29-42)	210	1		
7	Badger (Taxidea taxus)		Aug-Sept	Me		(183-265)	3(1-7)		
8	Bat (Eptesicus fuscus)		Fall	Me[4]	150	35	2(1-4)	1-3	Pr
9	Bat, vampire (Desmodus rotundus)		All yr	Pe	5+ mo			1+	Po
10	Bear (Ursus horribilis)	(2-3) yr	June-July	Me		209(180-225)	2(1-4)		Mo
11	Beaver (Castor canadensis)	2 yr	Jan-Feb			120(65-128)	4(1-6)		
12	Bobcat (Lynx rufus)		Late Feb			50	3(1-4)		
13	Buffalo (Bison bison)	3 yr	All yr[5]	Pe	21	275(270-285)	1(1-2)	1	Po
14	Camel (Camelus spp)		All yr	Pe	(10-20)	(315-410)	1		
15	Cat (Felis catus)	(6-15) mo	Feb-July	Pe[6,7]	(15-28)	63(52-69)	4		Pr
16	Cattle (Bos taurus)	(6-14) mo	All yr	Pe	(14-23)	281(210-335)	1	1	Po, Pr
17	Chinchilla (Chinchilla laniger)	4 mo	All yr[8]	Pe	28	(105-115)		(1-8)	
18	Chimpanzee (Pan troglodytes)	(8-9) yr	All yr	Pe	(34-35)	237(216-261)	1[3]		
19	Chipmunk (Tamias striatus)	(2.5-3) mo	Mar-July	Pe		31	(3-6)	2	
20	Deer (Cervus elaphus)	♂ 3.5; ♀ 2.5 yr	Sept-Oct	Pe		234(225-246)	1[3]		Po, Pr
21	Dog (Canis familiaris)	(6-8) mo	Spring-fall	Me	9	63(53-71)	7(1-22)[9]		Pr
22	Eland (Taurotragus oryx)		All yr	Pe	21	260(255-270)	1		
23	Elephant (Elephas maximus)	(8-16) yr		Pe	3-410	624(510-720)	1		
24	Elk (Alces alces)		Sept-Oct	Me	14	(240-250)	1[3]		Po
25	Ferret (Mustela putorius)		Mar-Aug	Pe[6]		(42-45)	8.5	(5-13)	
26	Fox (Vulpes fulva)	10 mo	Dec-Mar[11]	Me	(2-4)[12]	52(49-56)	(4-9)		Po
27	Gibbon (Hylobates lar)	8-10 yr	All yr	Pe	(29-30)	210	1		
28	Giraffe (Giraffa camelopardalis)		July-Sept	Pe		(400-480)	1		
29	Gnu (Connochaetes taurinus)	♀ 2 yr	June	Pe		(240-270)			
30	Goat (Capra hircus)	8 mo	Sept-winter	Pe[7]	21	148(135-160)	(1-5)		Pr
31	Gopher (Geomys breviceps)	3 mo	Mar-Aug	Pe		(40-50)	3(1-7)	1-3	
32	Guinea pig (Cavia porcellus)	(55-70) da	All yr	Pe	16	68(58-75)	3(2-8)		
33	Hamster (Mesocricetus auratus)	(5-8) wk	All yr	Pe	4	16(15-18)	(1-12)	3	
34	Hare (Lepus americanus)	1 yr	Mar-Aug	Pe		30(30-38)	3(1-7)	1	Pr
35	Hedgehog (Erinaceus europeaus)	2nd yr	Mar-Sept	Me		(35-49)	5(3-7)	1	
36	Hippopotamus (Hippopotamus amphibius)		All yr	Pe	30	231(210-250)	1		
37	Horse (Equus caballus)	1 yr	All yr[13]	Pe[7]	(10-37)	336(264-420)	1		
38	Hyena (Crocuta crocuta)		All yr	Pe	14	(91-110)	1		
39	Jaguar (Panthera onca)		Sept-Oct			(93-110)	(2-4)		
40	Kangaroo (Macropus rufus)		Once a yr			(38-40)	1		
41	Leopard (Panthera pardus)		All yr			(92-105)	3(1-4)		
42	Lion (P. leo)	2 yr	All yr	Pe	21	(105-113)	(1-6)		
43	Lynx (Lynx canadensis)		Early Mar			60	(1-5)		
44	Marmoset (Hapale jacobus)	♀ 14 mo				146(140-150)	2(1-3)		
45	Marten (Martes foina)	2 yr	July-Aug	Me		(255-285)	(3-5)		
46	Monkey (Macaca mulatta)	3 yr	All yr[14]	Pe	28	164(155-180)	1		
47	Mouse (Mus musculus)	35 da	All yr	Pe	4	19(19-31)	6(1-12)	(4-6)	
48	Muskrat (Ondatra zibethica)	1 yr	Apr-Oct	Pe		30(19-42)	7(1-11)	2	Mo, Pr
49	Nutria (Myocaster coypus)	8 mo	All yr	Pe	(24-29)	(120-150)	10		
50	Otter (Lutra canadensis)	1 yr	Feb	Me		60	(1-4)		
51	Panther (Felis concolor)		All yr[15]			(90-93)	3	(1-2)	
52	Swine (Sus scrofa)	7(5-8) mo	All yr	Pe	21	114(101-130)	9(6-15)[9]		Po
53	Platypus (Ornithorhynchus paradoxus)	(1-2) yr	July-Oct	Me	60		2		
54	Porcupine (Erethizon dorsatus)	3rd yr	Nov-Dec	Me		112	1(1-4)		
55	Rabbit (Oryctolagus cuniculus)	(5.5-8.5) mo	All yr	Pe[6]		31(30-35)	8(1-13)[9]		
56	Raccoon (Procyon lotor)	1 yr	Jan-June	Pe		63(60-73)	4(1-6)		
57	Rat (Rattus norvegicus)	(37-67) da	All yr[16]	Pe	4-5	21(21-30)	12(4-20)	2	Pr
58	Reindeer (Rangifer tarandus)	1.5 yr	Sept-Oct			230(210-246)	1[3]		
59	Rhinoceros (Didermocerus sumatrensis)	20 yr	July-Oct	Me		210	1		
60	Sable (Martes sibellina)	2 yr	June-Aug	Pe	(9-12)	(270-285)	(1-4)		
61	Sea lion (Zalophus californisanus)		June-July	Me		(348-365)	1		
62	Seal (Arctocephalus pusillus)	2 yr	Oct-Dec			(330-360)	2(1-2)		
63	Sheep (Ovis aries)	(7-8) mo	Fall[17]	Pe	(16-21)	151(144-152)	(1-4)[9]		Pr
64	Shrew (Sorex araneus)	2nd yr	Mar-Sept	Me		(35-49)	5(3-7)	1	
65	Skunk (Mephitis mephitis)		Mar		(9-10)	62	3-8)		
66	Squirrel (Sciurus carolinensis)	(1-2) yr	Dec-Aug			44	4(1-6)	(1-2)	Pr
67	Tapir (Tapirus terrestris)		Seasonal[18]			397(392-405)			
68	Tiger (Panthera tigris)	1.5 yr	All yr			(105-112)	3(1-6)		
69	Vole (Microtus agrestis)	♂ 6-8; ♀ 3 wk	Feb-Oct	Pe		21(21-29)	4		Pr
70	Walrus (Odobenus rosmarus)	4-5 yr	Apr-July			365(330-370)			
71	Wapiti (Cervus canadensis)	3 yr	All yr[17]	Pe	21	255(249-262)	1[3]	1	Po
72	Waterbuck (Kobus ellipsiprymnus)		May-July	Pe	21	240	1		
73	Whale (Balaenoptera borealia)	2 yr	May-Aug	Pe		360	1		
74	Wolf (Canis lupus)	2 yr	Dec-Apr			63	(3-9)	2	
75	Woodchuck (Marmota monax)	1 yr	Mar-Apr			28	4		
76	Woodrat (Neotoma micropus)		All yr	Pe		33	2(2-3)		
77	Zebra (Equus quagga)		Mar-Nov			(340-365)	1		

/1/ 274-280 days from 1st day of last menses, 267 days from ovulation. /2/ Twins in 83 births; triplets in 6, 889 births, quadruplets in 571,787 births, etc. /3/ Usually. /4/ Ovulation in spring. /5/ Peak, July-Sept. /6/ Induced ovulation. /7/ Seasonally. /8/ Peak, late fall-winter. /9/ Differs with strain or breed. /10/ In captivity. /11/ Peak, late Jan-Feb. /12/ Period of sexual receptivity. /13/ Mainly spring-summer. /14/ Except summer; Oct-Jan, fertile months. /15/ Peak, Jan. /16/ Except winter. /17/ Few breeds all year. /18/ Prior to rainy season. /19/ Peak, Sept-Oct.

The amount of time or activity engaged in by each sex (as indicated in column headings) in nest building, incubation, or feeding and care, is represented by symbols ranging from 0 (no time or activity) to ++++ (100% of activity).

	Order, Family	Common Name	Nest Building		Incubation				Feeding and Care of Young			
			Male	Female	Duration da	Male	Female	Attentive Periods [1]	Male Feeds Female	Nestling Period [2] da	Male	Female	Trips per Hour [3]
	Struthioniformes												
1	Struthionidae	Ostriches	++++	0	42	+++	+	9-15 hr	0	0	++	++	
	Rheiformes												
2	Rheidae	Rheas			35-42	++++	0		0	0	++++	0	
	Casuariiformes												
3	Dromiceiidae	Emus, cassowaries			58-61	++++	0	Continuous	0	0	++++	0	
	Apterygiformes												
4	Apterygidae	Kiwis	++	++	75	++++	0	Up to 7 da	0	6	++++	0	
	Tinamiformes												
5	Tinamidae	Tinamous			21	++++	0		0	0	++++	0	
	Sphenisciformes												
6	Spheniscidae	Penguins	++	++	38-56	++	++	1-5+ da	0	56-112	++	++	1-2/da
	Gaviiformes												
7	Gaviidae	Loons			28-30	++	++		0	0	++	++	
	Colymbiformes												
8	Colymbidae	Grebes	++	++	21-27	++	++	0.5-5 hr	0	0	++	++	
	Procellariiformes												
9	Diomedeidae	Albatrosses	++	++	63-80	++	++	5.3-21.8 da	0	150-251	++	++	2-5/wk
10	Procellariidae	Fulmars, shearwaters	++	++	51-58	++	++	1-7 da	0	49-95	++	++	0.5-2/da
11	Hydrobatidae	Storm petrels	++	++	38-50	++	++	1-5 da	0	56	++	++	1/da
12	Pelecanoididae	Diving petrels	++	++	56	++	++	1 da	0	54	++	++	1-2/da
	Pelecaniformes												
13	Phaethontidae	Tropic-birds			28	++	++		+	62	++	++	2-3/da
14	Pelecanidae	Pelicans			28-42	++	++		0	14-35	++	++	3+/da
15	Sulidae	Boobies	++	++	42-45	++	++	1 da	0	45+	++	++	1+/da
16	Phalacrocoracidae	Cormorants	++	++	24-25	++	++	1-3 hr	0	35-42	++	++	1
17	Anhingidae	Anhingas				++	++				++	++	
18	Fregatidae	Man-o'war birds	++	++		++	++				++	++	
	Ciconiiformes												
19	Ardeidae	Herons, bitterns	++	++	18-28	++	++	1-6 hr	0	10-52	++	++	0.5-3
20	Scopidae	Hammerheads	++	++	21	++	++			42	++	++	
21	Ciconiidae	Storks	++	++	30-38	++	++	1-4.5 hr	0	63	++	++	5-11/da
22	Threskiornithidae	Ibises	++	++	21-24	++	++	6-18 hr	0	42+	++	++	12-20/da
23	Phoenicopteridae	Flamingos			30-32	++	++	12 hr		3-4	++	++	
	Anseriformes												
24	Anhimidae	Screamers	++	++	42	++	++	7-17 hr	0	0			
25	Anatidae	Swans, geese, ducks	+	+++	21-35	+	+++	4-23.7 hr	0	0	+	+++	
	Falconiformes												
26	Cathartidae	Vultures			39-56	++	++		0	56-70	++	++	
27	Accipitridae	Hawks	+	+++	28-56	+	+++	1-20 hr	+++	28-133	++	++	0.1-4
28	Falconidae	Falcons	+	+++	28-29	+	+++	3 hr	+++	25-35	++	++	0.3-5.8
	Galliformes												
29	Megapodiidae	Megapodes	++++	0	57-70	0	0		0	0			
30	Cracidae	Chachalacas	++	++	22-24	0	++++			0			
31	Tetraonidae	Grouse, ptarmigans	0	++++	21-27	0	++++	6-11.5 hr	0	0	+	+++	
32	Phasianidae	Quail, pheasants	++	++	21-28	+	+++	7-23+ hr	0	0	++	++	
33	Meleagrididae	Turkeys	0	++++	28	0	++++	23-24 hr	0	0	0	++++	
34	Opisthocomidae	Hoatzins	++	++									
	Gruiformes												
35	Mesoenatidae	Monias				+++	+		0		+++	+	
36	Turnicidae	Bustard-quail	++	++	12-13	++++	0		0	0	++++	0	
37	Pedionomidae					++++	0		0	0	++++	0	
38	Gruidae	Cranes	++	++	29-32	++	++	44-165 min	0	0	++	++	
39	Rallidae	Rails	++	++	19-24	++	++	38 min	++	0-2	++	++	
40	Rhynochetidae	Kagus	++	++	36	++	++						
41	Eurypygidae	Sun-bitterns	++	++	27	++	++		0	21	++	++	
42	Otididae	Bustarda			20-25	0	++++			0	0	++++	
	Charadriiformes												
43	Jacanidae	Jacanas			23	++++	0				++++	0	
44	Rostratulidae	Painted snipes				+++	(?)						
45	Haematopodidae	Oyster-catchers			24-27	++	++	12 hr	0	0	++	++	
46	Charadriidae	Plovers	++	++	23-28	++	++	0.5-2.3 hr	0	0	++	++	
47	Scolopacidae	Sandpipers			18-29	++	++	11-15 hr	0	0	++	++	
48	Recurvirostridae	Avocets	++	++	23	++	++	10-66 min	0	0			
49	Phalaropodidae	Phalaropes	++++	0	20-21	+++	+		0	0	+++	+	
50	Burhinidae	Thick-knees			26-27	++	++		0	0			
51	Glareolidae	Pratincoles				+	+++						
52	Stercorariidae	Skuas, jaegers			23-26	++	++			0	++	++	
53	Laridae	Gulls, terns	++	++	20-34	++	++	0.5-24 hr	+	0- several	++	++	0.2-7
54	Rhynchopidae	Skimmers				0	++++		0	0	++	++	
55	Alcidae	Murres, puffins, guillemots	++	++	24-42	++	++	12 hr	+	2-49	++	++	
	Columbiformes												
56	Pteroclididae	Sand grouse			22-28	++	++	12 hr	0				
57	Raphidae	Solitaires			49	++	++						
58	Columbidae	Pigeons, doves	++	++	12-19	++	++	4-20 hr	0	10-35	++	++	0.2-1

/1/ Time hird sits on eggs at one sitting before leaving to feed and rest. /2/ Time from hatching until the hirds leave the nest. /3/ Unless otherwise indicated.

92. INCUBATION, NESTLING, AND PARENTAL ATTENTIVENESS: BIRDS (Concluded)

The amount of time or activity engaged in by each sex (as indicated in column headings) in nest building, incubation, or feeding and care, is represented by symbols ranging from 0 (no time or activity) to ++++ (100% of activity).

	Order, Family	Common Name	Nest Building		Incubation					Feeding and Care of Young			
			Male	Female	Duration da	Male	Female	Attentive Periods [1]	Male Feeds Female	Nestling Period [2] da	Male	Female	Trips per Hour [3]
	Psittaciformes												
59	Psittacidae	Parrots	+	+++	17-31	+	+++	Continuous	++++	28-36	++	++	
	Cuculiformes												
60	Cuculidae	Cuckoos	++	++	11-18	++	++	0.5-1.5 hr	0	6-22	++	++	2-12
	Strigiformes												
61	Tytonidae	Barn owls			30-34	+	+++		+++	56-64+	++	++	1.4-2.0
62	Strigidae	Owls	++	++	27-35	+	+++	23.5 hr	+++	21-35	++	++	1-8
	Caprimulgiformes												
63	Caprimulgidae	Goatsuckers	0	0	16-20	+	+++	1.4-14 hr	+	0	++	++	3.7
	Apodiformes												
64	Apodidae	Swifts	++	++	17-21	++	++	32-75 min	+	20-42	++	++	0.7-2.5
65	Trochilidae	Hummingbirds	0	++++	16-17	0	++++	5-99 min	+	19-25	0	++++	1.1-3.3
	Trogoniformes												
66	Trogonidae	Trogons	++	++	18-19	++	++	2-16 hr	0	16-30	++	++	2.0-2.4
	Coraciiformes												
67	Alcedinidae	Kingfishers	++	++	21-23	++	++	1.7-24 hr	+	24-35	++	++	1.9-3.8
68	Momotidae	Motmots	+	+++	17-21	++	++	1-5 hr	0	28-30	++	++	4.0-4.8
69	Meropidae	Bee-eaters	++	++	22	++	++	15-30 min		30	++	++	
70	Coraciidae	Rollers			18-19	++	++			26-28	++	++	
71	Upupidae	Hoopoes			16	0	++++	11.5 hr	++++	29	++	++	1.9
72	Phoeniculidae	Wood hoopoes									++	++	3
73	Bucerotidae	Hornbills	++	++	28-40	0	++++	Continuous	++++	75	+++	+	1.6-2+
	Piciformes												
74	Galbulidae	Jacamars	+	+++	19-22	++	++	145 min	+	20-26	++	++	
75	Bucconidae	Puffbirds	++	++		++	++	58 min	0				
76	Capitonidae	Barbets	++	++	13-15	++	++	37 min	+		++	++	
77	Ramphastidae	Toucans			16	++	++	38 min	0	43-45	++	++	3.4
78	Picidae	Woodpeckers	+++	+	11-18	+++	+	22-147 min	0	19-35	+++	+	1-30
	Passeriformes												
79	Dendrocolaptidae	Wood hewers	++	++	15a	++	++	27 min	0	19	++	++	9.7
80	Furnariidae	Oven birds	++	++	15-20	++	++	22-97 min	0	13-29	++	++	2-4
81	Formicariidae	Antbirds	++	++	14-17	++	++	79-180 min	0	9-13	++	++	1.3-5.3
82	Cotingidae	Cotingas	+	+++	18-19	0	++++	12-37 min	0	19-25	++	++	
83	Pipridae	Manakins	0	++++	19-21	0	++++	111 min	0	13-15	0	++++	1.2
84	Tyrannidae	Tyrant flycatchers	+	+++	14-21	0	++++	9-57 min	+	12-24	+	+++	3.7-35.0
85	Menuridae	Lyrebirds	0	++++	28	0	++++			42	0	++++	
86	Alaudidae	Larks	0	++++	11-12	+	+++		+	9-12	++	++	5.9-8
87	Hirundinidae	Swallows	++	++	14-18	+	+++	6-33 min	+	18-28	++	++	4-40
88	Oriolidae	Old world orioles	+	+++	14-15	+	+++			14-15	++	++	
89	Corvidae	Crows	++	++	16-20	+	+++	35-94 min	+++	15-38	+	+++	1.7-4
90	Paradiseidae	Birds of paradise	0	++++	14-18	+	+++	16-36+ min	0	18-31	+	+++	12.9
91	Paridae	Titmice	++	++	13-15	+	+++	10-38 min	++	14-21	++	++	3.6-34.5
92	Sittidae	Nuthatches	++	++	15	0	++++	31 min	++	22-24	++	++	11.9-18.4
93	Certhiidae	Creepers	+	+++	15	+	+++		+	15-20	++	++	
94	Chamaeidae	Wren-tits	++	++	15-16	++	++	47 min	0	15-16	++	++	8.8
95	Timaliidae	Babbling thrushes	+	+++	21a	+	+++		+		+	+++	
96	Cinclidae	Dippers	+	+++	16	+	+++	31 min	+	19-24	+	+++	8.8-25.9
97	Troglodytidae	Wrens	++	++	14-19	0	++++	12-86 min	+	13-22	++	++	5.6-19.2
98	Mimidae	Thrashers, catbirds	+	+++	12-13	+	+++	20.6-22.7 min	0	11-14	++	++	3.6-14.2
99	Turdidae	Thrushes	+	+++	12-14	+	+++	12-120 min	+	12-18	++	++	5.5-38.5
100	Sylviidae	Old world warblers	+	+++	12-15	+	+++	11-80 min	+	9-14	++	++	10-33
101	Regulidae	Kinglets	++	++	14-17	0	++++		0	18-20	++	++	17.5
102	Muscicapidae	Old world flycatchers	++	++	12-20	+	+++	15-87 min	++	10-20	++	++	6.2-33.6
103	Prunellidae	Accentors, hedge sparrows	+	+++	12-15	+	+++	19-30 min	+	13	++	++	5.1
104	Motacillidae	Pipits	+	+++	13-14	+	+++	19-48 min	+	10-15	+	+++	3.6-25
105	Bombycillidae	Waxwings	++	++	12	+	+++	37 min	+++	16	++	++	5.0
106	Ptilogonatidae	Silky flycatchers	+++	+	15	++	++	9 min	+	18-19	+++	+	2.5-5.3
107	Artamidae	Wood-swallows	+++	+		+++	+		0		++	++	
108	Laniidae	Shrikes	++	++	16	+	+++	23 min	+++	15-21	++	++	
109	Prionopidae	Wood-shrikes	++	++		++	++	17-30 min			++	++	7-10.9
110	Sturnidae	Starlings	++	++	12	++	++	20 min	0	20-21	++	++	19-22
111	Meliphagidae	Honey-eaters	+	+++	13-18	+	+++		0	14-18	++	++	9
112	Nectariniidae	Sun birds	+	+++	12-13	+	+++				+	+++	20
113	Dicaeidae	Flower-peckers	+	+++		+	+++				++	+	
114	Zosteropidae	White-eyes	++	++	11-12	++	++		0	9-11	++	++	7
115	Vireonidae	Vireos	+	+++	13-14	+	+++	10-38 min	0	11-13	++	++	3.9-13.5
116	Coerebidae	Honey creepers	+	+++	12-14	0	++++	19-61 min	0	14-19	++	++	4.7-13.2
117	Parulidae	Wood warblers	+	+++	11-17	0	++++	23-110 min	+	8-14	++	++	1.6-27.4
118	Ploceidae	Weaver finches	+++	+	12-16	+	+++	14 min	0	13-19	+	+++	4-20
119	Icteridae	Blackbirds	0	++++	11-16	+	++++	9-30 min	+	9-34	+	+++	6.2-17.7
120	Thraupidae	Tanagers	+	+++	12-16	0	++++		++	10-24	++	++	
121	Fringillidae	Finches, sparrows	+	+++	11-14	+	+++	14.6-continuous	++	8-17	++	++	1.3-21.3

/1/ Time bird sits on eggs at one sitting before leaving to feed and rest. /2/ Time from hatching until the birds leave the nest. /3/ Unless otherwise indicated.

93. NESTING SUCCESS: SOME PRECOCIAL AND ALTRICIAL BIRDS

Precocial young are hatched covered with down and ready to leave the nest in a few hours. Altricial young are born blind and naked, and need parental brooding and feeding for some time; when they leave the nest they are covered with feathers and can walk or hop and are soon able to fly. In some respects fledging of altricials corresponds to hatching of precocials.

Part 1: SUCCESS OF OPEN NESTS: ALTRICIAL SPECIES

Data adapted by Nice, M. M.

	Species	Nests			Eggs				
		Total	Successful		Total	Hatched		Fledged	
			Number	%		Number	%	Number	%
1	Mourning dove (Zenaidura macroura)	249	130	52.8	500			213	42.6
2		592	309	52.2					
3		4273	2043	47.9	8018	4379	54.6	3734	46.6
4		235	122	52.0					
5		204	142	69.6	398	310	77.8	274	68.8
6	Horned lark (Otocoris alpestris)	30	18	60.0	102	79	77.4	46	45.1
7	American robin (Turdus migratorius)	136	78	57.3	259	157	60.6	131	54.4
8		64	49	76.6					
9		176	86	48.8	548	316	57.8	246	44.9
10	Whinchat (Saxicola rubetra)	129	57	44.4					
11	Cedar waxwing (Bombycilla cedrorum)	60	46	76.7	245	189	77.1	171	69.8
12	Redwing (Agelaius phoeniceus)	67			214	156	72.9	105	49.1
13		356			1140	823	72.2	675	59.2
14	Yellow-headed blackbird (Xanthocephalus xanthocephalus)	128			443	314	70.9	99	22.4
15	Brewer's blackbird (Euphagus cyanocephalus)	107	53	49.5	521	327	62.7	205	39.3
16	Bronzed grackle (Quiscalus versicolor)	62	34	54.8	288	209	72.6	135	46.9
17	Goldfinch (Spinus tristis)	35	21	60.0	161	113	70.2	80	49.7
18		239			696	455	65.3	338	48.6
19	McCown's longspur (Rhyophanus mccowni)	45	27	60.0	153	92	60.1	71	46.4
20	Corn bunting (Emberiza calandra)	54			207			126	60.9
21		53	40	76.7	204			144	70.6
22	Chipping sparrow (Spizella passerina)	88	55	62.5	277	185	66.8	170	61.4
23	Field sparrow (S. pusilla)	593	226	38.1	1738	888	51.1	620	35.7
24	Song sparrow (Melospiza melodia)	147	77	52.4	585	389	66.5	243	41.5
25		76	30	39.5	321	147	45.8	80	24.9
26	Seven species	43	18	41.9					
27	Eight species	240	99	41.2					
28	Twenty-five species	246	101	41.0					
29	Ten species	30	20	66.6	145	93	64.1	70	48.3
30	Species (number not specified)	156			687	420	61.1	300	43.7
31	Eleven species	71			265	160	60.4	124	46.7
32	Six species	113			428	295	68.9	248	55.6
33	Eleven species				2151	1299	60.4	1010	46.9
34	Six species	121	57	47.0	421	257	61.0	170	40.4
		Summary[1]							
35	25 Studies, nest success	8034	3938	49.0					
36	24 Studies, hatching success of eggs laid				20,204	12,052	59.7		
37	22 Studies, hatching success of passerine eggs				11,788	7,363	62.5		
38	27 Studies, fledging success of eggs laid				21,115			9,728	46.1

/1/ The frequency of the percentages of hatching success in the 24 studies is: 1, 40-49; 3, 50-59; 12, 60-69; 8, 70-79. The median is 64.7%, in contrast to the 59.7% average of the 20,204 eggs. It is clear that this figure is biased by the low success (54.6%) of the 8,018 mourning dove eggs. Mourning doves build notoriously frail nests. Omitting the two mourning dove studies, the hatching success of the 11,788 passerine (song birds) eggs is 62.5%. The frequency of the percentages of fledging success in the 27 studies is: 2, 20-29; 2, 30-39; 14, 40-49; 4, 50-59; 3, 60-69; 2, 70-79. The median is 46.9%, which corresponds closely to the 46.1% average for the 21,115 eggs.

Part II: HATCHING SUCCESS OF SOME PRECOCIAL SPECIES: GALLINACEOUS BIRDS

Data adapted from Hickey, J. J., "Recent Studies in Avian Biology," edited by Albert Wolfson, University of Illinois Press: Urbana, 1955.

	Species	Place	Number of Nests	Per Cent Successful
1	Ring-necked pheasant (Phasianus colchicus)	Iowa	446	23
2		Pennsylvania	310	20
3		Ohio	563	58
4		Utah	149	36
5		Iowa	527	26
6	California quail (Lophortyx californica)	California	96	18
7	Bobwhite quail (Colinus virginianus)	Georgia, Florida	602	36
8		Texas	189	46
9	European partridge (Perdix perdix)	Michigan	143	32
10		Wisconsin	435	32
11	Summary: 10 studies on Phasianinae		3299	35.5
12	Willow ptarmigan (Lagopus lagopus)	Norway	125	63
13		Norway	107	80
14	Ruffed grouse (Bonasa umbellus)	New York	1431	61.4
15	Prairie chicken (Tympanuchus cupido)	Wisconsin	100	50
16	Sage grouse (Centrocercus urophasianus)	Utah	161	60
17		Colorado	238	35
18		Wyoming	134	34
19	Summary: 7 studies on Tetraonines		2296	57.5
20	Total summary: 17 studies		5595	44.5

93. NESTING SUCCESS: SOME PRECOCIAL AND ALTRICIAL BIRDS (Concluded)

Precocial young are hatched covered with down and ready to leave the nest in a few hours. Altricial young are born blind and naked, and need parental brooding and feeding for some time; when they leave the nest they are covered with feathers and can walk or hop and are soon able to fly. In some respects fledging of altricials corresponds to hatching of precocials.

Part III: SUCCESS OF SOME HOLE-NESTING ALTRICIAL SPECIES

Data adapted from Allen, R. W., and Nice, M. M., American Midland Naturalist, 47:606-665, 1952.

	Species	Years Observed	Nests	Eggs	Hatched		Fledged	
					Number	%	Number	%
1	Tree swallow (Iridoprocne bicolor)	9	219	1123	928	83.4	679	61.0
2		3	352	1759	1424	81.0	857	48.7
3		3	80	430	310	72.1	303	70.5
4		2	37	184	163	88.6	123	66.8
5		8	60	363	358	98.6	340	93.7
6	Pied flycatcher (Muscicapa hypoleuca)	8	221	1074			789	73.5
7	Black-capped chickadee (Parus atricapillus)	2	71	74			53	71.6
8	Great tit (P. major)	5	202	1936	1653	85.4	1416	75.1
9		19	5011	45,466			29,529	64.9
10		2	66	460	425	92.4	340	72.4
11		2	623	6012	4579	76.2	3938	65.5
12	Blue tit (P. caeruleus)	5	183	1887	1548	82.0	1453	77.0
13		2		247	185	75.0	168	68.0
14		4	37	286	187	65.0	128	44.7
15		2	46	413	366	88.6	327	79.2
16	Coal tit (P. ater)	1	18	161	153	95.0	131	81.4
17	House wren (Troglodytes aedon)	19	1056	6673	5576	82.3	5351	79.0
18		3	34	211	135	64.0	118	55.2
19		6		469			339	83.7
20		21	64	333	199	59.7	161	48.3
21	Bewick wren (Thryomanes bewicki)	15	21	129			79	56.8
22	Bluebird (Sialia sialis)	11	1401	6260	3943	63.0	2786	44.5
23		2	86	377	302	80.1	274	72.7
24		3	301	1290			839	65.0
25		9	67	272	213	78.3	172	63.2
26		20	50	203	131	64.5	127	62.5
27	Starling (Sturnus vulgaris)			10,557			7923	75.1
28		6		472			410	84.5
29	Prothonotary warbler (Protonotaria citrea)	11	121	413	159	38.5	106	25.7
30		2	36	163	100	61.3	100	61.3
31	House sparrow (Passer domesticus)	6		114			97	78.5
32	Five species	2		755			500	66.2
	Summary							
33	22 Studies (7 species) on hatching success			30,276	23,537	77.7		
34	32 Studies (14 species) on fledging success			90,676			60,016	66.2

94. BREEDING HABITS: REPTILES

In many of the ovoviviparous forms there exists a type of placentation, verging in some cases on viviparity, however, to avoid confusion, the term viviparous is not used. All reptiles have internal fertilization. Values in parentheses are ranges, estimate "q" of the 95% range (cf Introduction).

	Species	Sexual Maturity[1] yr	Breeding Season[2]	Manner of Birth	Gestation or Incubation Time[3]	Brood[4] Size[5]	Brood[4] No./yr
	Crocodilia						
1	Alligator, American (Alligator mississipiensis)	5-10	Jan-Sept	Oviparous	56-66	29-88	1
	Sauria						
2	Chameleon, false (Anolis carolinensis)	♂ 2; ♀ 1	Apr-Aug	Oviparous	6-7 wk	1	8-10
3	Gila monster (Heloderma suspectum)			Oviparous	30	5-13	1
4	Lizard, alligator (Gerrhonotus multicarinatus)		May	Oviparous	51-60	8-20	1
5	Lizard, collared-, western (Crotaphytus collaris)	<1-<3	May-June	Oviparous	8-13 wk	4-24	1
6	Lizard, night desert (Xantusia vigilis)	♀ 3	May-June	Ovoviviparous	3 mo	2(1-3)	1
7	Lizard, Pacific fence (Sceloporus occidentalis)	2	Mar-Apr	Oviparous	2 mo	9(6-13)	1
8	Lizard, sagebrush (Sceloporus graciosus)		Apr-May	Oviparous	62	2-7	1
9	Lizard, Texas horned (Phrynosoma cornutum)		Apr-May	Oviparous	39-47	23-37	1
10	Racerunner, common tessellated (Cnemidophorus tigris)		May-June	Oviparous	80	2-4	1-2
11	Skink, common five-lined (Eumeces fasciatus)	<2	May-June	Oviparous	4-9 wk	2-18	1
12	Slowworm (Anguis fragilis)	3-4	May-June	Ovoviviparous	3 mo	7-19	1
13	Uta, northern ground (Uta stansburiana)		Apr-May	Oviparous	61-67	2-4	1
	Serpentes						
14	Bullsnake (Pituophis catenifer)	<3	Apr-May	Oviparous	70(64-71)	3-19	1
15	Copperhead (Ancistrodon contortrix)	3-4	Apr-May	Ovoviviparous		142	2-10
16	Cottonmouth (A. piscivorus)		Mar-Apr; fall	Ovoviviparous	5 mo	3-15	1
17	Racer, western blue (Coluber constrictor)		May-June	Oviparous	1-2 mo	15-25	1
18	Racer, western striped (Masticophis taeniatus)	3	Apr-May	Oviparous			1
19	Rattlesnake, Gt. Basin (Crotalus viridis)	3-4	Apr-June	Ovoviviparous	4-5 mo	3-13	0.5
20	Snake, brown (Storeria dekayi)		Mar-Apr	Ovoviviparous	4 mo	14(13-26)	1
21	Snake, common garter (Thamnophis sirtalis)	2-3	Mar-May; fall	Ovoviviparous	87-116	28(6-51)	1-2
22	Snake, hog-nosed (Heterodon platyrhinos)		Apr-May	Oviparous		8-40	1
23	Snake, mud (Farancia abacura)		July	Oviparous	110[6]	22-104	1
24	Snake, Pacific rubber (Charina bottae)	2-3	June	Ovoviviparous		3-5	1
25	Snake, water (Natrix erythrogaster)		Apr-May	Ovoviviparous	120-150	8-27	1
	Testudinata						
26	Terrapin, diamondback (Malaclemys terrapin)	5-6	Spring	Oviparous	3 mo	4-9	1-3
27	Tortoise, desert (Gopherus agassizii)	15-20	May	Oviparous	80-120	2-13	1
28	Turtle, Atlantic loggerhead (Caretta caretta)		Mar-July	Oviparous	31-65	120-130	2-3
29	Turtle, common box (Terrapene carolina)	3-5	Apr-May	Oviparous	88(70-114)	2-7	1
30	Turtle, common musk (Sternotherus odoratus)	♂ 2-3; ♀ 9-11	Apr-Oct	Oviparous	60-75	1-6	1-2
31	Turtle, common snapping (Chelydra serpentina)		Apr-Nov	Oviparous	81-90	25(8-80)	1-2

/1/ Males in some species mature before females. /2/ Varies with geographical distribution. /3/ Accepted average expressed in da; other values in wk or mo are approximations. /4/ Broods or clutch. Brood = young produced at one time; clutch = eggs laid at one time. /5/ Number of eggs or young. /6/ From one observation only.

95. BREEDING HABITS: AMPHIBIANS

Data should be considered with caution. Growth, particularly, may be modified greatly by changes in temperature, moisture, and light. Breeding data may vary when mating and egg laying are not concurrent but take place at the extremes of the cited season as, for example, with some salamanders.

	Species	Breeding Season	Eggs or Young per Clutch	Fertilization	Place of Egg Development	Form at Hatching or Birth	Period of Growth to Sexual Maturity		
							Egg	Larva	Adult
							da		
	Urodela								
1	Eel, congo (Amphiuma tridactylum)[1]	May-Nov	42-150	Internal[12]	Terrestrial[13]	Larva		2-3 yr	
2	Eel, mud (Siren intermedia)[1]		224-706		Aquatic	Larva		2 yr	
3	Hellbender (Cryptobranchus alleganiensis)[1]	Aug-Sept	300-450	External	Aquatic[4]	Larva	64-84	540	5-6 yr
4	Mudpuppy (Necturus maculosus)[1]	Sept-June	18-180	Internal[12]	Aquatic[3]	Larva	38-63		5 yr
5	Newt, eastern (Diemictylus viridescens)[1]	Apr-June	200-375	Internal[5]	Aquatic[6]	Larva	20-35	80	2 yr
6	Salamander, Eschscholtz (Ensatina eschscholtzii)[1]	Oct-Apr	12-14	Internal[5]	Terrestrial[3]	Adult			
7	Salamander, European (Salamandra salamandra)[1]	July	12-72	Internal	[8]	Larva[9]		90-150	4-5 yr
8	Salamander, four-toed (Hemidactylium scutatum)[1]	Apr-Oct	22-64	Internal[5]	Terrestrial[3]	Larva	38-60	48	2½ yr
9	Salamander, green (Aneides aeneus)[1]	May-June	10-26	Internal[5]	Terrestrial[3]	Adult		84-91	
10	Salamander, marbled (Ambystoma opacum)[1]	Sept-Jan	50-200	Internal[5]	Terrestrial[3]	Larva	30-180	180-240	410-510
11	Salamander, slimy (Plethodon cinereus)[1]	Oct-Dec	3-13	Internal[5]	Terrestrial[3]	Adult[10]			2 yr
12	Salamander, spotted (Ambystoma maculatum)[1]	Mar-Apr	To 250				31-54	61-110	2 yr
13	Salamander, tiger (A. tigrinum)[1]	Jan-Mar	23-110		Aquatic[6]	Larva	24-30	75-118	360
14	Salamander, two-toed (Eurycea bislineata)[1]	Jan-Apr	12-41	Internal[5]	Aquatic[6]	Larva	60-70	2-3 yr	
15	Hynobius chinensis)[11]	May	35-70	External	Aquatic[4]	Larva		60	
	Anura								
16	Bullfrog (Rana catesbeiana)[1]	Feb-Aug	10,000-25,000	External	Aquatic[6]	Embryo	4-5	2 yr	2-3 yr
17	Frog (Eschasnus parvulus)[12]	July	30	External	Terrestrial[6]	Adv. tadpole		17	
18	Frog, Chilean (Rhinoderma darwini)[12]			External	Internal[13]	Adult			
19	Frog, chirping (Arthroleptella hewitti)[14]	October	36		Terrestrial	Adv. tadpole		10	
20	Frog, common (Rana temporaria)[1]	Feb-Apr	1,000-4000	External	Aquatic[6]	Embryo	14-21	90-180	4-5 yr
21	Frog, cricket (Acris gryllus)[1]	All year	250	External	Aquatic[6]	Embryo	4	50-90	2 yr
22	Frog, leopard (Rana pipiens)[1]	Feb-Dec	1200-1500	External	Aquatic[6]	Embryo		60-90	1-2 yr
23	Frog, New Zealand (Leiopelma hochstetteri)[15]	Dec-mber	6-18	External	Terrestrial[16]	Adult		30	
24	Toad, bell (Ascaphus truei)[1]	May-Sept	28-50	Internal	Aquatic[6]	Embryo	30	365	
25	Toad, common tree (Hyla versicolor)[1]	Apr-July	1000-2000	External	Aquatic[6]	Embryo	4-5	45-65	1-3 yr
26	Toad, Fowler's (Bufo woodhousei)[1]	Apr-Aug	8000	External	Aquatic[6]	Embryo	2-4	40-60	
27	Toad, narrow mouth (Microhyla carolinensis)[1]	May-Sept	850	External	Aquatic[6]	Embryo	2	20-70	2 yr
28	Toad, spadefoot (Scaphiopus holbrooki)[1]	Jan-Dec	100+	External	Aquatic[6]	Embryo	0.5+	18-28	
29	Toad, Surinam (Pipa pipa)[12]			External	Aquatic[17]	Adult			
30	(Discoglossus pictus)[1]	Jan-Oct	300-1000	External	Aquatic[6]	Embryo	2-4	30-60	
31	(Xenopus laevis)[14]	Sep-Oct	<100-1000	External	Aquatic[6]	Embryo	3	35-300	1 yr
	Apoda								
32	Caecilian (Typhlonectes compressicauda)[12]		6	Internal	Internal[3, 18]	Adult			

/1/ North America. /2/ From spermatophore deposited by male in female cloaca. /3/ Protected by female. /4/ Protected by male. /5/ From spermatophore laid by male and picked up by female. /6/ No parental protection. /7/ Europe. /8/ Carried by female. Viviparous form. /9/ Or adult. /10/ Gills at hatching or disappear before hatching. /11/ China. /12/ South America. /13/ In female vocal sac. /14/ Africa. /15/ New Zealand. /16/ Sex of protector not determined. /17/ On back of female. /18/ Viviparous form.

96. BREEDING HABITS: FISH

Data should be considered with caution because spawning activities vary widely with such factors as the species, area, and temperature of the water. Number of eggs may vary with size of female. A = salt water; B = pelagic or buoyant eggs; C = demersal eggs; D = fresh water; E = fluviatile; F = lacustrine; G = anadromous; H = brackish water.

	Species	Spawning		Egg or Young	Number of Eggs	Type of Fertilization
		Season	Locale and Type			
1	Bass, largemouth (Micropterus salmoides)	Spring, summer	C D E F	Oviparous[1]	2,000-26,000	External
2	Bowfin (Amia calva)	Spring	C D E F	Oviparous[2]	23,000-64,000	External
3	Bullhead, brown (Ameiurus nebulosa)	Spring	C D E F	Oviparous[2]	2,000-10,000	External
4	Carp (Cyprinus carpio)	Spring, summer	C D F	Oviparous[2]	500,000-2,000,000	External
5	Cod, Atlantic (Gadus callarias)	Winter, spring	A B	Oviparous[2]	3,000,000-9,000,000	External
6	Dogfish, Atlantic spiny (Squalus acanthias)	All year	A	Ovoviviparous[2]	2-11	Internal
7	Eel, American (Anguilla rostrata)	Winter	A B	Oviparous	5,000,000-20,000,000	External
8	Eel, Conger (Conger oceanica)	Summer	A B	Oviparous[2]	3,000,000-7,900,000	External
9	Flounder, winter (Pseudopleuronectes americanus)	Winter, spring	A C	Oviparous	500,000-1,500,000	External
10	Gar, longnose (Lepisosteus osseus)	Spring	C D E F	Oviparous	36,500	External
11	Haddock (Melanogrammus aeglefinus)	Winter, spring	A B	Oviparous[2]	169,000-1,840,000	External
12	Hagfish, Atlantic (Myxine glutinosa)	All year	A C	Oviparous[2]	19-30	
13	Halibut, Atlantic (Hippoglossus hippoglossus)	Spring, summer	A B	Oviparous	2,183,000	External
14	Herring, Atlantic (Clupea harengus)	Spr., sum., aut.,	A C	Oviparous[2]	20,000-40,000	External
15	Lamprey, sea (Petromyzon marinus)	Spring	C D E G[4]	Oviparous[2]	236,000	External
16	Mackerel, Spanish (Scomberomorus maculatus)	Spring, summer	A B	Oviparous[2]	20,000	External
17	Mummichog (Fundulus heteroclitus)	Spring, summer	C D E H	Oviparous[2]	460	External
18	Pike, northern (Esox lucius)	Spring	C D E H	Oviparous[2]	10,000-100,000	External
19	Pumpkinseed (Lepomis gibbosus)	Spring, summer	C D E F	Oviparous[1]	Several thousand	External
20	Ray, southern sting (Dasyatis americana)		A	Ovoviviparous[2]	3-5	Internal
21	Salmon, Atlantic (Salmo salar)	Spring	C D E G[5]	Oviparous[2]	7000	External
22	Sea horse, northern (Hippocampus hudsonius)	Spring	A	Oviparous[1]	150	External
23	Shad (Alosa sapidissima)	Spring	C D E G	Oviparous[2]	100,000-156,000	External
24	Shark, hammerhead (Sphyrna zygaena)	Summer	A	Viviparous[2]	29-37	Internal
25	Shark, mun-eater (Carcharodon carcharias)	Summer	A	Vivip. or Ovovi.[2]	9	Internal
26	Skate, little (Raja erinacea)	All year	A C	Oviparous[2]	6	Internal
27	Stickleback, three spine (Gasterosteus aculeatus)	Spring	D H	Oviparous[1]	100-150	External
28	Sturgeon, Atlantic (Acipenser sturio)	Spring, summer	C D E G	Oviparous[2]	1,000,000-2,500,000	External
29	Trout, brown (Salmo trutta)	Autumn, winter	C D E[5]	Oviparous[6]	200-6000	External
30	Trout, rainbow (S. gairdneri)	Spr., sum., aut.,	C D E G[5]	Oviparous[6]	400-3000	External

/1/ Male guards nest or eggs. /2/ No parental care. /3/ Both parents guard nest or eggs. /4/ Dig shallow pits for nests on gravelly riffles. /5/ Clear, shallow, moving water on gravel nests or reeds. /6/ Eggs covered by gravel or sand.

97. BREEDING HABITS: AQUATIC INVERTEBRATES

Breeding habits of invertebrates vary with changes in location, temperature, light, and for marine forms, salinity. Asterisks indicate where data apply to specific locations providing the most complete information.

	Species and Location	Sexual Maturity		Eggs or Young per Brood	Type Sexuality	Breeding Season	Ovum Type
		Age[1]	Size[2] mm				
	Xiphosura						
1	Crab, horseshoe (Limulus polyhemus), Delaware Bay area*	9-11 yr	♂ 178-258[3]	Few-1000	Dioecious[4]	Apr-July	Oviparous
	Crustacea						
2	Crab, blue (Callinectes sapidus), Chesapeake Bay area*	♂♀ 13 mo	♂ 135-215[5]	1,750,000	Dioecious[4]	July-Aug	Oviparous
3	Crayfish (Orconectes immunis), New York State area*	♂♀ 15 mo	♂ 40-60[6]	102(84-195)	Dioecious[4]	June-Oct	Oviparous
4	Cyclops (Cyclops viridis), Germany*	♂ 41-132 da[7]	♀ 1.5-.[8]	75(20-160)[9]	Dioecious[4]	All year	Oviparous
5	Lobster (Homarus americanus), Delaware-Newfoundland*	4-5 yr	♂ 17-60[10]	8500[11]	Dioecious[4]	July-Sept	Oviparous
6	Waterflea (Daphnia longispina), northeastern U.S.A.*	♀ 75-86 hr	♂ 1.2; ♀ 1.9	28(4-35)	Dioecious[4, 12]	All year[13]	Oviparous
	Mollusca						
7	Chiton, gray (Schnochition magdalenensis), Calif.-Mexico	2 yr	35-36	57,970	Dioecious		Oviparous
8	Clam, hard shell (Venus mercenaria), Baja California*	1-2 yr	5-7		Monecious[14, 15]	July-Aug	Oviparous
9	Clam, piamo (Tivela stultorum), Pacific area	5 yr	10-12	750,000	Monecious[14, 15]		Oviparous
10	Clam, razor (Siliqua patula), eastern Pacific area*	2-4.2 yr	10-14		Dioecious[14]		Oviparous
11	Clam, soft shell (Mya arenaria), Arctic-N. Carolina; Pacific	1-2 yr			Dioecious[14]	May-Aug	Oviparous
12	Drill, oyster (Urosalpinx cinerea), Delaware Bay area*	15-25 mo	15-24	300-960	Dioecious[14]	Apr-Nov	Oviparous
13	Limpet (Acmaea digitalis), Alaska-Mexico				Dioecious[14]		Oviparous
14	Mussel (Mytilus edulis), cosmopolitan	1-2 yr			Dioecious	May-Sept	Oviparous
15	Nudibranch, red (Eurostanga pulchra), California			9-156	Monecious[14, 16]	Dec-Feb	Oviparous
16	Ormer (Haliotis tuberculata), Channel Islands-Europe	3 yr	5	10,000	Dioecious[14]	July-Sept	Oviparous
17	Oyster (Crassostrea virginica), Delaware Bay area	1 yr	25-50	½-1 million	Monecious[14, 15]	June-Aug	Oviparous
18	Periwinkle (Litorina littorea), North Atlantic-Florida			1-3	Dioecious[4]		Oviparous
19	Scallop, bay (Aequipecten irradiane), western Atlantic	12 mo	78		Monecious[14]		Oviparous
20	Scallop, giant (Placopecten magellanicus), North Atlantic*	3-4 yr	50-70		Dioecious[14]	June-Oct	Oviparous
21	Snail, burrowing (Polynices duplicatus), northern U.S.A.-Mexico	2 yr	>12		Dioecious[4]	June-Aug[17]	Oviparous
22	Snail, edible (Helix pomatia), Europe	33-39 mo		40-200	Monecious[14, 16]	May-July	Oviparous
23	Snail, pond (Lymnaea stagnalis), Wisconsin	4-14 mo	50-60	6,000	Monecious[14, 16]	July-Oct	Oviparous
24	Top-shell, great (Trochus niloticus), Indo-Pacific	2 yr	6-7		Dioecious[4]		Oviparous
25	Whelk, channelled (Busycon canaliculatum), Cape Cod-Mexico			360-6240	Dioecious[4]		Oviparous
26	Yoldia, file (Yoldia limatula), North Atlantic; Pacific				Dioecious[14]		Oviparous
	Echinodermata						
27	Starfish (Asterias forbesi), Long Island Sound*	1-2 yr	60-210[17]	Thousands	Dioecious[14, 15]	June-Aug	Oviparous

[1] At onset. [2] Greatest dimension. [3] ♀ 243-351; prosomal width. [4] Sexual dimorphism. [5] ♀ 134-185. [6] ♀ 44-90. [7] ♀ 36-128. [8] ♂ smaller. [9] In early summer. [10] ♀ 18-48. [11] Average difficult to obtain because females are disposed of before reaching maximum egg-laying age under present fisheries conditions. [12] Parthenogenetic reproduction most of season and illustrated by remaining data. [13] Except winter. [14] No sexual dimorphism. [15] Protandrous hermaphrodite: male organs appear first, later replaced by female organs. [16] Cross fertilization. [17] Dependent on food supply.

98. REPRODUCTION: INVERTEBRATES

Fertilization of the egg can be internal (Int) or external (Ext). Sex is indicated as monoecious(Mo) or dioecious (Di).

	Phylum (Class) [Genus]	Fertilization	Reproduction		Adult	
			Zygote	Development	Sex	Form
1	Porifera (Calcarea) [Sycon][1]	Int	In mesenchyme of sponge.	Amphiblastula.	Mo	Sponge.
2	Coelenterata (Hydrozoa) [Obelia][1]	Ext	Free.	Planula-colony-medusa buds.	Di	Hydroid colony.
3	Coelenterata (Scyphozoa) [Aurelia]	Int	In folds of oral lobes.	Planula-scyphistoma-ephyrae.	Di	Medusa.
4	Coelenterata (Anthozoa) [Metridium][1]	Ext	Free.	Planula.	Di	Polyp.
5	Platyhelminthes (Turbellaria) [Dugesia][1]	Int	In capsule.	Development direct.	Mo^2	Planaria.
6	Platyhelminthes (Trematoda) [Fasciola]	Int	In capsule.	Miracidium-redae-cercariae[3].	Mo^2	Liver fluke.
7	Platyhelminthes (Cestoda) [Taenia]	Int	In capsule.	Oncosphere-hexacanth-cysticercus.	Mo^4	Tapeworm.
8	Rhynchocoela [Cerebratulus][1]	Ext	Free.	Coelobiastula-pilidium	Di	Nemertine worm.
9	Rotifera [Philodina]	None	None.	Development direct.	Pi^5	Rotifera.
10	Nematoda [Ascaris]	Int	In shell.	To juvenile stage in open; completion in host.	Di	Intestinal worm.
11	Bryozoa (Gymnolaemata) [Bugula][1]	Int	In body of parent.	Trochophore larva.	Mo^4	Colony.
12	Bryozoa (Phylactolaemata) [Pectinatella][1]	Int	In body of parent.	Ciliated hollow larva gemmates.	Mo^4	Colony.
13	Brachiopoda [Lingula]	Ext	Free.	Trochophore larva.	Di	Brachiopod.
14	Mollusca (Pelecypoda) [Venus]	Ext	Free.	Trochophore larva-veliger larva.	Di	Quahog.
15	Mollusca (Pelecypoda) [Anodonta]	Int	Develops in gills of parent.	Glochidium parasitic on fish gill.	Mo	Mussel.
16	Mollusca (Gastropoda) [Buccinum]	Int	In capsule.	Trochophore larva-veliger larva.	Di	Whelk.
17	Mollusca (Gastropoda) [Helix]	Int	In ground.	Development direct.	Mo^2	Snail.
18	Mollusca (Cephalopoda) [Loligo]	Int	Encased in sticky secretion.	Development direct.	Di	Squid.
19	Annelida (Polychaeta) [Nereis]	Ext	Free.	Trochophore larva.	Di	Sandworm.
20	Annelida (Oligochaeta) [Lumbricus]	Int	In capsule.	Development direct.	Mo^2	Earthworm.
21	Arthropoda (Crustacea) [Cambarus]	Int	Fastened to swimmerets.	Development direct.	Di	Crayfish.
22	Arthropoda (Insecta) [Romalea]	Int	Laid in ground.	Nymph stages.	Di	Grasshopper.
23	Arthropoda (Insecta) [Ephemera]	Int	Laid in water.	Aquatic nymph.	Di	May fly.
24	Arthropoda (Insecta) [Pieris]	Int	Laid on plants.	Caterpillar-pupa.	Di	Butterfly.
25	Arthropoda (Insecta) [Melolontha]	Int	Laid in ground.	Grub-pupa.	Di	Beetle.
26	Arthropoda (Insecta) [Apis]	Int	Laid in hive.	Larva-pupa.	Di	Honeybee.
27	Echinodermata (Asteroidea) [Asterias]	Ext	Free.	Dipleurula-bipinnaria-brachiolaria	Di	Starfish.
28	Echinodermata (Ophiuroidea) [Ophioderma]	Ext	Free.	Dipleurula-ophiopluteus.	Di	Brittle star.
29	Echinodermata (Echinoidea) [Arbacia]	Ext	Free.	Dipleurula-echinopluteus.	Di	Sea urchin.
30	Echinodermata (Holothuroidea) [Cucumaria][1]	Ext	Free.	Dipleurula-modified auricularia.	Di	Sea cucumber.
31	Echinodermata (Crinoidea) [Antedon]	Ext	Attached to pinnules.	Dipleurula-ciliated larva-stalked crinoid.	Di	Feather star.
32	Hemichordata [Saccoglossus]	Ext	Free.	Free larva, gradual change to adult.	Di	Tongue worm.
33	Chordata (Cephalochordata) [Branchiostoma]	Ext	Free.	Development direct.	Di	Amphioxus.

[1] Also reproduce asexually. [2] Cross fertilization. [3] Miracidium free, sporocysts and rediae in snails, cercariae in water or on grass where they are picked up by ruminant. [4] Self-fertilization. [5] Parthenogenetic female.

99. REPRODUCTION: INSECTS

Data are to be considered with caution because duration of stages varies seasonally, geographically and climatically, in some cases duration of pupal and larval stages applies only under summer conditions. Where insects breed all year regardless of season, the cycle is continuous.
E = egg; L = larva; N = nymph; P = pupa; A = adult; Cont. = continuous.

	Species and Type Attacked[1]	Eggs per Female	Duration, days				Over-wintering Stage	Generations per Season	Host[2]; Stage
			E	L or N	P	A			
	Anoplura								
1	Louse, cattle (4 species) [1]	30-50	10-30	9-15		10-30	Cont.	7-10	Cattle; A, N
2	Louse, human (3 species) [1]	50-300	5-21	7-10		10-30	Cont.	10-12	Man; A, N
	Coleoptera								
	Beetle								
3	Black carpet (Attagenus piceus) [C]	42-114	6-11	238-638	6-24	32-72	i,	<1	Fabric; L
4	Carpet (Anthrenus scrophulariae) [C]	32	10-18	66	14		Cont.	1-3	Fabric; L
5	Cigarette (Lasioderma serricorne) [C]	30	>6	>30	14-21	21	L	5-6	Dry food; A, L
6	Colorado potato (Leptinotarsa decemlineata) [C]	>500	4-9	10-21	5-10		A	1-3	Potato, etc.; A, L
7	Confused flour (Tribolium confusum) [C]	300-400	4-14	>22	5-18	1000	A	5-6	Grain, flour; A, L
8	Dried-fruit (Carpophilus hemipterus [C]	>80	>3	28-120	9-14	15		>8	Fruit; L
9	Drug-store (Stegobium paniceum) [C]			20-150	12-18		L	3-6	Dry food; A, L
10	Flea (Systena spp) [C]	500-900	5-8	14-21	10-14		A	2-3	Potato; A, L
11	May (Phyllophaga fisca) [C]		21	>730	30	21-28	A, L	$\frac{1}{2}$	Crops, trees; A, L
12	Mexican bean (Epilachna varivestis) [C]	250-1200	5-14	20-35	10		A	3-4	Bean, cowpea; A, L
13	Red-legged ham (Necrobia rufipes) [C]	400-1000	>3	>17	>13	420	L	6-10	Meat, fish; A, L
14	Saw-toothed grain (Oryzaephilus surinamensis) [C]	45-285	>8	>30	>6	180-1100	Cont.	6-7	Grain, fruit; A, L
15	Striped cucumber (Acalymma vittata) [C]			14-40	7		A^3	1-4	Cucurbits; A, L
16	Borer, lesser grain (Rhyzopertha dominica) [C]	300-500						8-12	Wood, books; A, L
17	Cadelle (Tenebroides mauritanicus) [C]	436-1000	7-10	39-414	8-25	365	A, L	3	Grain, cereal; A, L
18	Curculio, plum (Conotrachelus nenuphar) [C]	41-175	4-10	17-48	8-30	365	A	1 to >1	Peach, apple, etc.; A, L
19	Mealworm, yellow (Tenebrio molitor) [C]	276	13-16	>600	18-20	60-90	L	>1	Grain; L
	Weevil								
20	Alfalfa (Hypera postica) [C]	200-800	13-17	17-21	7-14	14-21	A, E	1-2	Alfalfa; L
21	Bean (Acanthoscelides obtectus) [C]	200	5-20	11-40	8-18	14-63	A	2-5	Bean; L
22	Cotton boll (Anthonomus grandis) [C]	80-200	3-5	7-12	3-5	30-300	A	4-10	Cotton; A, L
23	Cowpea (Callosobruchus maculatus) [C]	82-196	4-6	9-240	5-18	15	A, L	8-10	Dried pea; L
24	Granary (Sitophilus granarius) [C]	50-250	4-8	19-34	8-16	210-250	Cont.	6-12	Grain; A, L
25	Sweetpotato (Cylas formicarius elegantulus) [C]		7	14-21	7		Cont.	6-8	Sweetpotato; A, L
	Diptera								
	Fly								
26	Horn (Siphona irritans) [C]	50-400	1-4	4-8	4-8	5-20	P	4-10	Cattle; A
27	Horse (Tabanus atratus) [C]	100-400	2-5	100-600	5-20	5-20	L	1-2	Animal; A
28	House (Musca domestica) [C]	75-200	1-3	4-10	4-18	10-50	Cont.	4-18	Garbage, manure; A
29	Stable (Stomoxys calcitrans) [C]	20-100	2-5	11-30	8-20	5-30	P	4-10	Animals; A
30	Vinegar (Drosophila spp) [C]		<1	3-11	2-8	14	A, L	5-6	Fruit, vegetables; A, L
31	Grub, cattle (Hypoderma spp) [C]	100-500	3-10	250-280	18-70	1-25	L	1	Cattle; A, L
32	Maggot, seed-corn (Hylemya cilicrura) [C]	100	1-8	7-16	10-20	30-35	Cont.	2-5	Corn, bean, etc.; L
33	Mosquito (hundreds of species) [C]	100-1036	2-1800	5-15	2-5	5-300	A, L, E	7-17	Animals; A
34	Yellow fever (Aedes aegypti)		2-365	6	2-3	15-60	Cont.		
35	Screwworm (Callitroga americana) [C]	100-300	1-2	4-5	5-40	5-30	None[4]	2-12	Animals; L
	Hemiptera								
36	Bug, harlequin (Murgantia histrionica) [I]	75-100	4-15	40-60			A, N	3-4	Cabbage, etc.; A, N
37	Bug, squash (Anasa tristis) [I]	200-300	7-14	28-42		15-110	A	1	Squash, etc.; A, N
	Homoptera								
38	Aphid, melon (Aphis gossypii)[I] [5]		90-120	3-7		7-28	A, E	20	Cotton, melon; A, N
39	Aphid, pea (Macrosiphum pisi) [I] [5]		90-120	10	5-20		E or Cont.	7-20	Pea, clover, etc.; A, N
40	Cicada, periodical (Magicicada septendecim) [I]		42-49	13-17 yr		30-40	N		
41	Greenbug (Toxoptera graminum) [I] [5]	3-7	90-120	6-30		26-60	A, N, E	5-20	Small grains; A, N
42	Leafhopper, beet (Circulifer tenellus) [I]	300-400	5-40	25-52		120-150	A	3-5	Beet, bean, etc.; A, N
43	Leafhopper, potato (Empoasca fabae) [I]	60-90	10	14		30	Cont.	2-4	Potato, bean; A, N
	Hymenoptera								
44	Bee, honey (Apis mellifera) [C] [5, 6		3	8	9	35-40	A		
45	Sawfly, wheat stem (Cephus cinctus) [C]	50	7-10	300	7-10	7	L	1	Wheat, grass; L
46	Wasp, digger (Tiphia vernalis) [C]	50-75	8-9	120-180	180-240	30-42	P	1	Japanese beetle; L
	Lepidoptera								
47	Bollworm, pink (Pectinophora gossypiella) [C]	200	4-10	14-21	12-18	14	L	3-6	Cotton; L
	Borer								
48	European corn (Pyrausta nubilalis) [C]	400	4-9	30-40	10-14	10-24	L	1-3	Corn, etc.; L
49	Peach tree (Sanninoidea exitiosa) [C]	200-600	7-48	270-380	16-25	4-16	L	1	Peach, etc.; L
50	Squash vine (Melittia cucurbitae) [C]	150-200	7-14	30	Winter		L, P	1-2	Squash, etc.; L
51	Sugarcane (Diatraea saccharalis) [C]	200	4-9	20-30	6-7	7-14	L	4-5	Sugarcane; L
52	Cabbageworm, imported (Pieris rapae) [C]	200-500	7	14	7-14		P	3-6	Cabbage, etc.; L
53	Earworm, corn (Heliothis armigera) [C]	1000	2-8	13-28	14	12	P	1-7	Corn, tomato; L
54	Hornworm, tobacco (Protoparce sexta) [C]	200-300	7	21-28	14-28		P	1-3	Tobacco, etc.; L
55	Leafworm, cotton (Alabama argillacea) [C]	400-600	3-20	7-21	7-21	10-24	None in U.S.	3-8	Cotton; L
	Moth								
56	Casemaking clothes (Tinea pellionella) [C]	>40	>6	30-100	10-90	7-28			
57	Codling (Carpocapsa pomonella) [C]	6-100	4-14	15-72	7-40	3-20	L	>1 to >3	Apple, pear, etc.; L
58	Indian-meal (Plodia interpunctella) [C]	200-400	7-14	13-288	>8	18	L	5	Grain; L
59	Mediterranean flour (Ephestria kuehniella)[C]	116-700	>3	40	5-7	3-4		>6	Millproducts; L
60	Oriental fruit (Grapholitha molesta) [C]	100-200	3-28	10-26	5-35	2-34	L	4-7	Peach, apple; L
	Mallophaga								
61	Louse, cattle biting (Bovicola bovis) [I]	20-50	7-30	15-25		10-30	Cont.	7-10	Cattle; A, N
	Orthoptera								
62	Cockroach, American (Periplaneta americana) [I]	200-1000	35-100	200-400		212-303	Cont.		
63	Grasshopper (many species) [I]	300-400	90-120	40-60		>30	E	1	Crops, grass; A, N
	Siphonaptera								
64	Flea (many species) [C]	50-400	2-13	7-30	7-35	8-150	Cont.	3-5	Animals; A
	Thysanoptera								
65	Thrips, gladiolus (Taeniothrips simplex) [I]	150	4-12	4-12	3-8	26-32	A	6	Gladiolus; A, N

/1/ [I] = incomplete metamorphosis (having external development of wings); [C] = complete metamorphosis (having internal development of wings until pupal stage). /2/ Host and/or food preference. /3/ Unmated. /4/ Migrates from warmer regions in spring. /5/ Parthenogenesis. /6/ Worker bees only.

100. OVUM MORPHOLOGY: VERTEBRATES

Part I: DIMENSIONS AND GENERAL CHARACTERISTICS

Ranges, where given, are estimate "d" of the 95% range (cf Introduction).
I = isolecithal; T = telolecithal; (+) = present; (-) = absent; NR = not recognisable.

	Species	Type	Polarity[1]	Diameter mm	Volume cu mm	Vitelline Membrane	Zona Pellucida[2] mm	Corona Radiata	Tertiary Membranes	Transport Time[3] da	Viability hr
1	Man	I	NR	0.089–0.091[4]		$+^{5}$	0.019–0.035[6]	+	-	3^{7}	24^{8}
2	Armadillo	I		0.080		+	+				
3	Bat	I	+	0.095–0.140		+	0.090–0.110	+	-	>21	
4	Cat	I	+	0.120–0.130		+	0.012–0.115	+	-	4–8	
5	Cat, marsupial	I	+	0.240	0.001	+	+		$+^{9}$		
6	Cow	I	NR	0.135–0.157		$\pm^{10}$	0.012–0.015	-	-	3–4	12–24
7	Dog	I	+	0.135–0.145		+	0.135	+	-	6–8	96–192
8	Ferret	I	+	0.116–0.132		$\pm^{10}$	0.004–0.006[11]	+	-	5–6	30
9	Fish	T^{12}		0.4–150	0.033–1.766						
10	Frog	T		0.7–10[13]	0.18–524[13]						
11	Goat	I	NR	0.140–0.145			0.0125	-	-	2.5–4	
12	Guinea pig	I	+	0.075–0.107		$\pm^{10}$	0.012	+	-	3.5	<26
13	Horse	I	NR	0.099–0.141		$+^{14}$	0.0135[11]	-	$+^{15}$	4	24
14	Hummingbird	T^{12}		(Shell 14 x 9.5)	113						
15	Lizard (Draco spp)	T^{12}		5	65						
16	Monkey, rheaus	I	+	0.109–0.173		$\pm^{10}$	0.0115–0.034[16]	+	-	3	<24
17	Mouse	I	+	0.070–0.087	0.00036	+	+	+	-	1.45	12
18	Opossum	I	$+^{17}$	0.130–0.160[18]	0.001	+	0.004–0.008[11]	-	$+^{19}$	2	
19	Ostrich	T^{12}		(Shell 155 x 130)							
20	Platypus	I	+	2.5–4.5[20]	8.2	+	$+^{11}$	-	$+^{21}$		
21	Rabbit	I	NR	0.110–0.146		$\pm^{10}$	0.011–0.023	+	-	2.5–4	6
22	Rat	I	NR	0.070–0.076		$\pm^{10}$	+	+	-	3	<12–33
23	Sheep	I	NR	0.120–0.180	0.0018	$+^{14}$	0.011–0.016	-	-	2–4	12–24
24	Snake (Python)	T^{12}		120 x 60	195–226						
25	Swine	I	NR	0.120–0.140		$\pm^{10}$	0.015	-	-	3–4	12–48

/1/ Of uncleaved egg. /2/ Values are mm membrane thickness. /3/ Time for ova to reach site of implantation or attachment. /4/ Unfertilized tubal egg with vitelline membrane only. With zona pellucida, 0.133; with corona radiata, 0.178–0.202. /5/ Very slight membrane, consists merely of cytoplasmic membrane of vitellus. /6/ Unfertilized tubal ova. /7/ Probably maximum time for non-segmenting ovum to reach uterine cavity. Time between fertilization and implantation, 6–7 da. /8/ Probably fertilizable for not more than 12 hr. /9/ Laminated albuminous layer and very thin shell membrane formed in the tube. /10/ Perivitelline space present. /11/ Homogenous and gelatinous. /12/ With meroblastic cleavage. /13/ Lower value for green frog, upper value for marsupial frog. /14/ Perivitelline space filled with finely granular material. /15/ In the tubal egg there is a thin albuminous coat. /16/ Clear, highly refractile membrane, sharply defined; inner third is pale iridescent blue. /17/ Determined by position of polar body. /18/ With shell membrane dimensions increase to 0.40–0.50 mm. /19/ Produced by secretory activity of oviduct, an albuminous coat 0.05 mm thick and a shell membrane 0.001 mm thick. /20/ Shell up to 6.5. /21/ Well developed membrane, consisting of an albuminous coat (more than 2 mm thick), a shell membrane, and a parchment-like shell.

Part II: CYTOPLASM AND NUCLEUS

	Species	Cytoplasm	Nucleus
1	Man	Transparent, colorless, finely granular, vitellus completely fills the space within zona.	Central. 1st polar body extruded and maturation spindle formed before ovulation. Nucleolus with chromatin.
2	Armadillo	Deutoplasmic granules.	One or two may be formed with maturation spindle, 1st spindle formed in ovary. Four young develop from one egg.
3	Bat	Fat droplets, yolk vesicles. Mitochondria concentrated in cortex.	1st polar body formed before ovulation. Polynuclear ova.
4	Cat	Deutoplasm with fat globules. Mitochondria concentrated in cortex. Polyovular follicles.	1st polar body extruded before, and 2nd maturation spindle established at ovulation. Polynuclear ova.
5	Cat, marsupial	Yolk accumulated at animal pole.	Pronuclei in granular formative cytoplasm. 1st polar body extruded in ovary.
6	Cow	Scattered fat granules (0.001–0.004 mm).	1st polar body formed before ovulation. Polynuclear ova may occur.
7	Dog	Highly refractile fat globules, so dense that vitellus is dark. Mitochondria concentrated in cortex.	Membrane, nucleolus, and/or chromatin visible; ovum discharged from ovary while nuclear material in germinative vesicle form. Polyovular follicles, polynuclear ova.
8	Ferret	Highly refractile fat granules, so dense that vitellus is dark.	1st polar body formed before ovulation. Ovulation only after coitus.
9	Goat	Fine fat granules, evenly distributed.	1st polar body formed before ovulation.
10	Guinea pig	Small fat globules at vegetal pole. Mitochondria scattered. Golgi apparatus as fenestrated membrane at periphery.	1st polar body formed before ovulation. Polynuclear ova.
11	Horse	Highly refractile fat globules, so dense that vitellus is dark.	1st polar body extruded before ovulation.
12	Monkey, rheaus	Yellowish, fine yolk granules. Vitellus fills zona. Polyovular follicles.	1st polar body extruded before ovulation. Polynuclear ova.
13	Mouse	Yellowish granular material and scattered non-fat yolk globules. Vitellus fills zona. Mitochondria first appear concentrated in periphery. Golgi bodies more numerous toward one pole.	Clear non-granular nucleus in center. 1st polar body formed in ovary. Polynuclear ova.
14	Opossum	Usually elliptical. Yolk differentiated in 3 zones. Fat chiefly in middle or submarginal zone. In some, large fat vacuole occurs at one pole, usually opposite polar body. Polyovular follicles.	1st polar body given off in ovary. Chromosomes, as with all mammals, are short rods in the form of open ring. Polynuclear ova.
15	Platypus	Bulk is formed of yellowish yolk spheres, up to 0.036 mm, dispersed in peripheral and central zone. Latebra in center of yolk.	0.014–0.20 mm in diameter. Diffusely staining, vesicular in character, has faint reticulum, dark-staining vacuolated nucleolus. 1st polar body given off in ovary. Egg normally monospermic.
16	Rabbit	Transparent. Mitochondria first appear concentrated in periphery. Golgi material is loose network of thick threads at periphery.	1st polar body extruded before ovulation. Polynuclear ova.
17	Rat	Optically heterogeneous, not transparent. 2 or 3 vacuoles detectable near center.	1st polar body formed before ovulation.
18	Sheep	Yellowish granular material, dense, numerous non-fat yolk globules. Mitochondria first appear concentrated in periphery. Polyovular follicles may occur.	1st polar body extruded before ovulation. Polynuclear ova may occur.
19	Swine	Yolk heavy with fat. Polyovular follicles may occur.	1st polar body formed before ovulation. Polynuclear ova may occur.

101. OVUM CHARACTERISTICS: MAMMALS

Part I: SEQUENCE AFTER SPERM PENETRATION

Values are hours unless otherwise specified.

	Animal	Starting Time[1]	Sperm Penetration	Second Polar Body Formation	Male Pronucleus Formation		Animal	Starting Time[1]	Sperm Penetration	Second Polar Body Formation	Male Pronucleus Formation
1	Man	O	<1 da		48 (?)	7	Hamster[2]	C	6-8[3]	>6	12-24[3]
2	Cat	C	2-3 da	Not < 22		8	Mouse	C	1/4-2	5-7	6-24[3]
3	Cattle	O			11-39	9	Rabbit	C	10-13	13-14½	14-18[3]
4	Ferret	C	6-30	<41	41-52	10	Rat	O	2-4	10-14+(C)	14-35 (C)
5	Fox, silver	1st C	2-3 da	>3-4 da		11	Sheep	C			<36
6	Guinea pig	C	10	13½	12-31	12	Weasel[4]	1st C	<53-80	>74	53-80[3]

/1/ O = ovulation; C = coitus. /2/ Golden. /3/ Approximately. /4/ Long-tailed.

Part II: ZYGOTE CLEAVAGE RATES

Values are hours unless otherwise specified; those indicated with an asterisk (*) are approximate.

	Animal	Starting Time	1st Cleavage Spindle	2-cell	4-cell	8-cell	16-cell	32-cell	Blastocoele Formation
1	Man	Ovulation							<5-8 da*
2	Cattle	Ovulation	27-32	27-42	31-54	50-83	4 da*	59-131*	8-9 da
3	Ferret	Coitus	53-70	51-71	64-74	64-116	95-120*		4½-6 da*
4	Goat	Coitus	30*	30-48*	48-60*	85*	120*		5 da*
5	Guinea pig	Coitus	27-38	23-48	30-75	80-82*	107*		115*
6	Hamster, golden	Coitus		24-36*	48-60*	72*	66-72*		78*
7	Horse			24	30-36		98-100*		
8	Mink	1st coitus		3 da*	3-4 da	4-7 da	5-6 da*	7 da*	
9	Monkey	Ovulation		26-49*	24-52*		4-6 da*		
10	Mouse	Coitus	21-28	21-43	38-50	50-64	60-70*	68-80*	66-82*
11	Pony	Ovulation		24*	33*	53*	98*		
12	Rabbit	Coitus	24	21-25	25-32	32-40	40-47*	48*	75-96*
13	Rat	Coitus	24-35	1-2 da	2-3 da	3-4 da	4 da*		4½ da*
14	Sheep	Coitus		38-39*	42*	42-44*	3 da*	4-5 da*	6-7 da*
15	Shrew	1st coitus		60-64	81				
16	Swine	Coitus	51*	25-51*	25-74*	90			5-6 da*
17	Weasel, long-tailed	1st coitus		70-85*	70-99*	99 hr- 8 da	8 da*	11 da*	11-15 da*

Part III. TRANSPORTATION OF ZYGOTE TO UTERUS AND TIME OF IMPLANTATION

	Animal	Starting Time	Age or Stage at Entry	Implantation Time		Animal	Starting Time	Age or Stage at Entry	Implantation Time
1	Man	Ovulation		8-13 da	13	Hedgehog		8 cell	
2	Armadillo, 9-banded		Blastocyst	4 mo	14	Mink	1st coitus	8 da; blastocyst	25 da
3	Badger, American			2 mo	15	Monkey	Ovulation	By 16 cell	9-11 da
4	Badger, European			6 mo	16	Mouse	Coitus	66-72 hr[1]	4-5 da
5	Cat		Early blastocyst		17	Opossum	Coitus	Pronuclear stage;	24 hr
6	Cattle	Ovulation	3-4 da; 8-16 cell	25-35 da	18	Platypus		1 cell	None
7	Deer, European roe			4 mo	19	Rabbit	Coitus	72-96 hr[1]	7-8 da
8	Echidna		1 cell	None	20	Rat	Coitus	3½-5 da[1]	5-6 da
9	Ferret	Coitus	117-144 hr[1]		21	Sheep	Coitus	72-96 hr	9-11 da
10	Goat	Coitus	32 hr		22	Squirrel, ground	Coitus	4 da; 4 cell	4-5 da
11	Guinea pig	Coitus	3½-4½ da; 4-8 cell	6 da	23	Swine	Coitus	4-5 da; 3-4 cell	11 da or less
12	Hamster, golden	Coitus	2½ da; 4-8 cell		24	Weasel, long-tailed	1st coitus	11-15 da[1]	8 mo

/1/ Late morula early blastocyst.

Part IV: INTRA- AND INTERSPECIFIC ZYGOTE TRANSFER

Data are for zygotes of pre-implantation stages transferred to host genital tracts.

	Donor	Host	Degree of Development		Donor	Host	Degree of Development
1	Cow	Cow	To term	10	Rabbit	Rabbit	To term
2	Cow	Rabbit	One cleavage	11	Rabbit	Mouse	One cleavage
3	Goat	Goat	To term	12	Rabbit	Rat	One cleavage; blastocoele formation
4	Goat	Sheep	Dead embryo at 45 da	13	Rabbit	Guinea pig	One cleavage
5	Guinea pig	Mouse	None	14	Rat	Rat	To term
6	Mouse	Mouse	To term	15	Rat	Rabbit	None
7	Mouse	Rabbit	One cleavage	16	Rat	Mouse	None
8	Mouse	Guinea pig	Development in blastocyst shape	17	Sheep	Sheep	To term
				18	Sheep	Goat	Stillborn
9	Mouse	Rat	One cleavage	19	Swine	Swine	To term

Part V: POLYPLOID AND PARTHENOGENETIC ROUTES OF DEVELOPMENT

	Type of Development	Possible Origin of Development Route[1]			Maximum State of Development Reported		
		2nd Polar Body	1st Cleavage	Sperm[3]	Age[2]		
					Mouse	Rabbit	Other Mammals
1	Diploidy, normal	Normal	Normal	Present	Normal development		
2	Triploidy	Suppressed	Normal	Present	9½ da embryo	Adult[4]	Pig: adult[4]
3	Tetraploidy	Normal	Suppressed	Present	3½ da blastula	4-cell	
4	Hexaploidy	Suppressed	Suppressed	Present	12-cell[5]		
5	Polyploidy (evolutionary origin)				Adults[6]	Adults[6]	Man[4]; hamster (tetraploid); rat (triploid)
					Parthenogenesis[7]		
6	Haploidy	Normal	Normal	Absent	3½ da blastula	8-cell	Ferret; 4-cell; guinea pig: 1-cell; sheep: 1-cell
7	Diploidy	Suppressed	Normal	Absent		Adult	
8	Tetraploidy	Suppressed	Suppressed	Absent		1-cell	

/1/ Suppression of 2nd polar body (= suppression of 2nd maturation division) can double maternal chromosomes. Suppression of 1st cleavage division can double maternal and paternal chromosomes combined. Presence or absence of sperm determines presence or absence of paternal chromosomes.
/2/ Embryonic age from coition. /3/ Gynogenesis (fertilization with genetically inactivated sperm) is classified as parthenogenesis (cf Fn 7).
/4/ Controversial results. /5/ Development route probable. /6/ Indirect evidence. /7/ Parthenogenesis = development of unfertilized ovum.

102. OVUM MORPHOLOGY: INVERTEBRATES

Because of space limitations, certain symbols are used to indicate the condition typical for the organism or class to which an organism belongs. In instances where there are exceptions to type within a class the symbol is followed by an asterisk (*). Symbols apply to the columns in the table as indicated in the following key:

EGG TYPE

Homolecithal	Ho
Telolecithal	Te
Centrolecithal	Ce

MEMBRANE

Vitelline membrane	Vi
Zonal radiata	Zr
Chorion	Ch
Tertiary membrane	Te

CLEAVAGE

Holoblastic	HO
Radial	Ra
Biradial or disymmetrical	Bi
Bilateral	Bl
Spiral	Sp
Meroblastic	ME
Superficial	Su
Discoidal	Di
Irregular	Ir

BLASTULATION

Coeloblastula	
Equal	EC
Unequal	UC
Placula	Pl
Stereoblastula	St
Morula	Mo
Stomoblastula	So
Superficial	Su
Discoblastula	Di

GASTRULATION

Emboly	EM
Epiboly	EP
Polar ingression	Pl
Unipolar	Un
Many-celled	Mc
Multipolar	Mp
Delamination	DE
Simple	Si
Coeloblastic	Co
Morula	Mo
Syncytial	Sy

MESODERM

Ectomesoderm	EC
Endomesoderm	
Teloblastic bande	Te
Secondary bands	Se
Enterocoele	En
Solid ingrowth	So
Mesenchyme	Me

COELOM

Acoelomate	Ac
Pseudocoelomate	Ps
Coelomate	Co
Schizocoele	Sc
Enterocoele	En

	Phylum (Class)[1] [Genus]	Egg Type	Membrane	Cleavage	Blastulation	Gastrulation	Mesoderm	Coelom
1	Porifera (Calcispongiae) [Scypha]	Ho		HO	EC, UC, Pl, So	EM, Sy		
2	Coelenterata[2] (Hydrozoa) [Tubularia]	Ho, Ce*	Te	HO, Sp*	St, Mo, Su*	All[3]		
3	Coelenterata[2] (Scyphozoa) [Aurelia]	Ho	Vi, Te	HO	St, Mo	EM, Mo		
4	Coelenterata[2] (Anthozoa) [Urticina, Actinia]	Ho, Ce*	Ch, Te	HO	EC, Mo	EM, Mp, Co		
5	Ctenophora (Nuda) [Beroe]	Ho		Bi	UC	EP	EC	
6	Platyhelminthes (Turbellaria) [Planocera, Yungia]	Te	Vi, Te	Sp	UC, Mo	EP		Ac
7	Platyhelminthes (Trematoda) [Polystomum]	Ho	Vi	HO, Di, Ir	UC, St		EC	Ac
8	Platyhelminthes (Cestoidea) [Taenia]	Ho	Vi	Ir		EP		Ac
9	Nemertea[4]	Te	Vi, Zr	HO, Sp	UC, St			Ac
10	Nemertea[4] (Heteronemertea)[5] [Cerebratulus]	Te	Vi, Zr	HO, Sp	UC	EM, Un	EC, Te	Ac
11	Nemertea[4] (Hoplonemertea)[5] [Tetrastemma, Prostoma]				UC*	Mc*		Ac
12	Acanthocephala (Archioacanthocephala)[5] [Macracanthorhynchus]	Te	Vi	HO, Sp	St	Un		Ps
13	Rotatoria[6] (Rotifera) [Asplanchna]	Te	Te	HO, Sp*		Un*	EC*	Ps
14	Gastrotricha[6] [Neogossea]	Te		HO, Ir, Sp*	UC	Un		Ps
15	Nematomorpha[6] [Gordius, Paragordius]	Ho		HO, Bi		EM, Co*	EC, Me*	Ps
16	Nematoidea[6] [Ascaris, Parascaris]	Ho	Vi, Te	HO, Bi	EC, Pl	EP	EC, Se	Ps
17	Tardigrada [Macrobotus]				EC	EM	En	Co, En
18	Chaetognatha [Sagitta]	Te		Ra	UC	EP	En	Co, En
19	Bryozoa (Entoprocta) [Loxosoma, Pedicellina]	Ho		HO, Sp	UC	EM	EC, Te*	Ps
20	Bryozoa (Ectoprocta) [Bugula]	Ho	Zr*	HO, Ra	UC, Pl	Pl, Un	Me	Co
21	Brachiopoda [Terebratulina]			HO, Sp*, Ir	EC	EM	En	Co, En
22	Phoronidea [Phoronus]				EC	EM, Un	EC, Me	Co, En
23	Enteropneusta [Saccoglossus]		Vi, Ch			EP	En	
24	Echinodermata (Crinoidea) [Antedon]	Te	Ch	HO, Bi, Ir*		EM	Me, En	Co, En
25	Echinodermata (Asteroidea) [Asterias]	Ho	Ch	Ra	UC	EM	En	Co, En
26	Echinodermata (Ophuroidea) [Amphiura]	Ho	Ch	Ra	EC	EM	En	Co, En
27	Echinodermata (Echinoidea) [Echinus]	Ho	Ch	Ra	EC	EM	En	Co, En
28	Echinodermata (Holothuroidea) [Synapta]	Ho	Ch	Ra, Su*	EC	EM	En	Co, En
29	Priapuloidea[6] [Priapulus]	Ho		HO, Ir		EM	En	Co, En
30	Annelida (Archiannelida) [Polygordius]	Te	Vi, Zr[7]	HO, Sp	UC, Pl	EP	EC, Te	Co, Sc
31	Annelida (Polychaeta) [Nereis, Eupomotus]	Te		HO, Sp	UC, St	EM*, EP	EC, Te	Co, Sc
32	Annelida (Oligochaeta) [Criodrilus]	Te	Vi	HO, Sp	UC, Mo	EM*, EP	EC, Te	Co, Sc
33	Annelida (Hirudinea) [Clepsine, Nephelis]	Te	Vi	HO, Sp	UC	EP	EC, Te	Co, Sc
34	Echiuroidea (Echiurida) [Echiurus, Urechis]	Te		HO, Sp	UC	EP	Te	Co, Sc
35	Sipunculoidea [Phascolosoma]		Vi, Zr	HO, Sp	UC, St*	Pl, Un	EC, Te	Co, Sc
36	Onychophora [Peripatus]	Te		ME, Su	St, Su	EM, EP	Se	Co, Sc
37	Arthropoda (Pycnogonida) [Pycnogonium]			ME				Co, Sc
38	Arthropoda (Scorpionea)[5] [Euscorpius]	Te		ME, Di	Di	EM, St	Se	Co, Sc
39	Arthropoda (Acari)[5] [Tromidium]	Ce		ME, Su	Su			Co, Sc
40	Arthropoda (Araneae)[5] [Agiena, Argiope]			ME, Su	Su		Se	Co, Sc
41	Arthropoda (Branchiopoda)[8] [Branchypus, Artemia]	Ce	Vi, Te	ME, Su	Su	Mp	Se	Co, Sc
42	Arthropoda (Cladocera)[5] [Daphnia]	Ce	Vi, Te		Su	Mc	Se	Co, Sc
43	Arthropoda (Ostracoda)[8] [Cypris]	Ce	Vi, Te	ME, Su	Su	Mp	Se	Co, Sc
44	Arthropoda (Copepoda)[8] [Cyclops]	Ce	Vi, Te	ME, Su	Su	Un	Se	Co, Sc
45	Arthropoda (Cirripedia)[8] [Balanus, Lepas]	Ce	Vi, Te	ME, Su	Su	Un	Se	Co, Sc
46	Arthropoda (Myaidacea)[5] [Mysis]	Ce	Vi, Te	ME, Su	Su	Mp, Si	Se	Co, Sc
47	Arthropoda (Amphipoda)[8] [Gammarus]	Ce	Vi, Te	ME, Su	Su	Si		Co, Sc
48	Arthropoda (Decapoda)[5] [Gallinectes, Astacus]	Ce	Vi, Te	ME, Su	Su	Si	So	Co, Sc
49	Arthropoda[9] (Symphyla) [Scolopendra]	Ce	Ch	ME, Su	Su	Si	So	Co, Sc
50	Arthropoda [Musca, Dytiscus]	Ce	Vi, Zr, Ch, Te[10]	ME, Su	Su			Co, Sc
51	Arthropoda (Hymenoptera)[5] [Platygaster]							Co, Sc
52	Mollusca (Crepipoda) [Chiton, Ischnochiton]	Te	Vi, Zr, Ch	HO, Sp	UC, St	EM, Un	EC, Te	Co, Sc
53	Mollusca (Gastropoda) [Patella, Crepidula]	Te	Te, Ch	HO, Sp	UC, St	EP, Un, Mc	EC, Te	Co, Sc
54	Mollusca (Scaphopoda) [Dentalium]	Te	Ch	HO, Sp	UC	Pl, EP, Un	EC, Te	Co, Sc
55	Mollusca (Pelecypoda) [Unio, Dreissensia]	Te	Vi	HO, Sp	UC	EM, Un, Mc	EC, Te	Co, Sc
56	Mollusca (Cephalopoda) [Loligo, Sepia]	Te	Vi, Ch, Te[11]	ME, Di	Di	EM	Se	Co, Sc

/1/ Unless otherwise noted. /2/ Also called Cnidaria. /3/ Except EP. /4/ Also called Rhynchocoela. /5/ Order. /6/ Currently included in phylum Aschelminthes by many investigators. /7/ Identified by some observerers as zona radiata, by others as cortical cytoplasm. /8/ Subclass. /9/ Also called Myriapoda. /10/ Chorion present in parasitic forms. /11/ Fertilization membrane is formed as sperm enters egg.

103. CORPUS LUTEUM OF PREGNANCY: VERTEBRATES

(A)=time of maximum development; (B)=time of appearance of retrogressive changes; (C)=period during which ovariectomy is followed by abortion. Comparable data for corpus luteum during "normal" cycles are to be found under the appropriate designations in the footnotes.

	Animal	Corpus Luteum During Pregnancy	Fate of Theca Interna Cells
		Mammals	
1	Man (Homo sapiens)	(A) 7th-10th wk. (B) Gradually from 7th to 12th wk. (C) Up to 8th wk but also performed at end of 4th wk without abortion.[1]	Form paralutein cells. "K" cells may invade gland. Form 8% of pregnancy corpus.
2	Armadillo, nine-banded (Dasypus novemcinctus)	Large during period of delayed implantation. (A) At implantation. (B) Middle of pregnancy. (C) At time of implantation.[2]	
3	Baboon, Chacma (Papio porcarius)	(A) 3rd wk. (B) Falls after 4-5 wk, then constant for 26 wk. Disappears rapidly after parturition.[3]	Form the vascular reticular system.
4	Bat, big-eared (Corynorhinus rafinesquei)	(A) Shortly after attachment of blastocyst. (B) Early in pregnancy.	
5	Bat, little brown (Myotis lucifugus)	Pre-ovulatory luteinization of granulosa cells. (A) 4th-5th da.	No true differentiation of theca interna occurs.
6	Bat, vampire (Desmodus rotundus murinus)	(A) When blastocyst is present in oviduct. (B) After mid-pregnancy.	Do not participate in gland formation.
7	Cat (Felis catus)	(A) 10th-16th da. (B) 20th da. Rejuvenated during lactation and may persist for 6-8 mo from mating. (C) Up to 50th da.	Migrate into gland on 2nd da. Resume fibroblastic appearance after 3rd da. Some remain at periphery.
8	Cat, marsupial (Dasyurus viverrinus)	(A) 3rd da. (B) Persists for 7-8 wk (lactation) then declines. No trace after 4th mo.	May contribute connective tissues.
9	Cow (Bos taurus)	(A) 90th da. (B) 150th da. Central cavity present in gland; marked color changes occur. (C) Always.[4]	Invade luteal tissue from 6th da. May become connective tissue.
10	Deer, fallow (Dama dama)	(A) 30th da onwards. (B) Still active at 150 da.	Invade luteal tissue.
11	Dog (Canis familiaris)	(A) 18th da. (B) After 30th da. (C) During 1st half of pregnancy, at least. Remains throughout anestrus.	
12	Elephant, African (Loxodonta africana)	(A) Accessory corpora formed early or at ovulation. All retrogress at mid-term. (B) Replacement corpora persist until term, then decline rapidly.	Form an investing layer which retains its character after parturition.
13	Ferret (Mustela furo)	(A) 3rd-5th wk. (B) 3-4 da before parturition.	
14	Goat (Capra hircus)	(A) 30th da. (B) Slowly from 60th da. (C) Always.[5]	Invade luteal tissue but can be distinguished for several wk.
15	Guinea pig (Cavia porcellus)	(A) 20 da. (B) After parturition. (C) After mid-pregnancy.[6]	Hypertrophy and rapidly become indistinguishable from luteal cells.
16	Hamster, golden (Cricetus auratus)	(A) 2-3 da. (B) Rapidly after parturition. (C) Between 11th and 12th da.[7]	
17	Hedgehog (Erinaceus europaeus)	(B) During lactation.[8]	
18	Horse (Equus caballus)	(A) 14th da. (B) 35th-40th da followed by large crop of accessory corpora lutea which degenerate from 150th da. (C) Before 200th da.[9]	Incorporated in luteal tissue. May hypertrophy markedly in pregnancy.
19	Mink (Mustela vison)	(A) 10th-12th da. Inactive phase during delayed implantation. Persists through pregnancy and 4-5 wk post-partum.	Migrate into gland 10-18 hr after ovulation.
20	Monkey (Macaca mulatta)	(A) Up to 19th da as on 12th da. "Transition" stage 19th-24th da. (B) 25 da. (C) Up to 25th da.[10]	Retained until 4th da (not distinguishable 4th-6th da). As paralutein cells in pregnancy corpus.
21	Mouse (Mus musculus)	(A) 9th-11th da. (B) Present but active at parturition. (C) Throughout pregnancy.[11]	Proliferate actively during 1st da. Invade luteal tissue in relation to capillaries but may become connective tissue. No trace after 36-60 hr.
22	Opossum, Virginian (Didelphis virginiana)	(A) 3rd da. (B) 12-13 da, disappears by 3rd mo. (C) Always.[12]	Do not contribute any glandular elements.
23	Platypus (Ornithorhynchus paradoxus)	(A) Time of formation of blastocyst. (B) Shortly before egg is laid.	Invade luteal tissue and also remain in groups at periphery of gland.
24	Rabbit (Oryctolagus cuniculus)	(A) 8th da; maximum diameter at mid-pregnancy. (B) Resorbed slowly after parturition. (C) Always followed by abortion or resorption.	Invade corpus and said to form vascular and connective tissue.
25	Rat (Rattus rattus)	(A) 9th-11th da. (B) Slowly after parturition. (C) Throughout pregnancy but not always after 14th da.[13]	Early proliferation. May form luteal cells.
26	Seal, common (Phoca vitulina)	(B) Heavily vacuolated at parturition but persists for several weeks.	Remain as paralutein cells in early pregnancy.
27	Seal, northern fur (Callorhinus ursinus)	Luteal cells heavily vacuolated during delayed implantation. (A) Larger at 1 yr of age than at 2-3 mo. (B) Heavily vacuolated at parturition but persists for 2 mo more.	Remain as paralutein cells in early pregnancy but do not appear active during period of delayed implantation or from a few wk after.
28	Sheep (Ovis aries)	(A) Remains large from 14th da. (B) 120th-140th da. (C) May not be after 55th da.[14]	Invade luteal tissue but atrophy rapidly.
29	Shrew, elephant (Elephantulus myurus)	(A) At 10 mm embryo stage but continues to increase in size. (B) At 30 mm embryo stage.[15]	Form a core to everted corpus and may give rise to connective tissue.
30	Shrew, mole (Blarina brevicauda)	(A) At 3 mm embryo stage. (B) Rapid after 7 mm embryo stage; vanished at parturition.	
31	Shrew, water (Neomys fodiens bicolor)	Corpora merge with interstitial tissue at 4-8 cell ovum stage.	Enlarge in early pregnancy.
32	Swine (Sus scrofa)	(A) 75th da. (B) 110th da.[16]	Some invade luteal tissue early. Some remain at periphery of gland.
33	Whale, blue (Balaenoptera musculus)	Appears active during pregnancy. Degenerates after parturition but corpus albicans persists for many years.	Invade gland in radial strands. May become connective tissue after parturition.
34	Whale, casing (Globicephala melaena)	(A) Young corpus has heavily vacuolated cells. (B) Persists in degenerate form after parturition.	Some remain at periphery of gland.
		Birds	
35	Fowl (Gallus domesticus)[17]	Postovulatory follicle retrogresses rapidly with no lutealization of granulosa after 2 da.	Deposit collagenous fibers and later disappear.

/1/ (A) 6th da stage of maturity. (B) 10th da onwards. /2/ Breeds in July with implantation in November. /3/ (A) 7th-8th da. (B) 13th da. /4/ (A) 9th-10th da. (B) 14th-16th da. /5/ (A) 9th da. (B) 12th da. No trace by 6 wk. /6/ (A) 9th-10th da. (B) 11th da. /7/ (A) 2nd da. (B) Rapidly after 3rd da. /8/ Granulosa cells not luteinized, gland shrinks steadily to time of next ovulation. /9/ (A) 12th-14th da. (B) 14th da. /10/ (A) 8th da. (B) 13th da. Corpora aberrantia persist 23 wk. Accessory corpora in 17% of cycles. /11/ (A) 2nd-3rd da. (B) 3rd da. /12/ (A) 3rd da. (B) 7-8 da; almost disappeared by 20th da. /13/ (A) 2nd-3rd da. (B) After 3rd da. /14/ (A) 6th-8th da. (B) 14th da; trace by 24th da. /15/ (A) At mid-dense stroma stage of uterus. (B) At same time as pre-menstrual change in uterus. /16/ (A) 6th-9th da. (B) 13th-16th da. /17/ Also, cowbird (Molothrus bonariensis). Removal of ruptured follicle causes holding of oviduct egg beyond time of lay 1-7 da.

103. CORPUS LUTEUM OF PREGNANCY: VERTEBRATES (Concluded)

(A)=time of maximum development; (B)=time of appearance of retrogressive changes; (C)=period during which ovariectomy is followed by abortion. Comparable data for corpus luteum during "normal" cycles are to be found under the appropriate designations in the footnotes.

	Animal	Corpus Luteum During Pregnancy	Fate of Theca Interna Cells
		Reptiles	
36	(Amphibolurus muricatus)	(A) 1st-2nd wk. (B) 3rd wk; disappears 2 wk after laying.	May grow into gland to provide blood vessels and connective tissue.
37	Gecko (Hoplodactylus maculatus)	(A) At 30 somite stage. (B) At 33 mm embryo stage.	Play no part in gland formation.
38	Lizard (Lygosoma quoyi)	(A) About 2nd wk. (B) End of 2nd mo.	No ingrowth among luteal cells.
39	Lizard (Xantusia vigilis)	(A) 4th wk. (B) 8th-9th wk. Disappears 4th wk post-partum.	Surround corpus. May contribute vascular and connective tissue elements.
40	Lizard, blindworm (Anguis fragilis)	Persists during development of embryo.	Remain at periphery of corpus.
41	Lizard, green (Lacerta viridis)	Present during gestation.	May give rise to connective tissue.
42	Lizard, viviparous (L. vivipara)	(A) 1 mo after ovulation. (B) End of 2nd mo. [Later may give rise to supporting connective tissue of corpus.]	Form peripheral cellular layer at first.
43	Snake, brown (Storeria dekayi)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Resorption or abortion if performed in middle of gestation.	
44	Snake, garter (Thamnophis sirtalis and T. radix)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Normal delivery if performed late in gestation.	Contribute to supporting tissue of corpus. Luteinization of theca cells.
45	Snake, N. American garter (Natrix cyclopion)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Normal delivery if performed in late pregnancy; resorption or abortion if in early or in middle of pregnancy.	
46	Snake, sea (Enhydrina schistosa)	Starts to retrogress slowly from 44 mm embryo stage.	Hypertrophy after ovulation and contribute connective tissue ingrowths to the gland.
47	Snake, sea (Hydrophis cyanocinctus)	(A) 195 mm embryo stage. (B) Degenerates after parturition.	Little distinction between theca interna and theca externa.
48	Turtle, box (Terrapene carolina)	Persists until egg laying. (B) Degenerated by 6-9 wk later.	Hypertrophy and form part of gland on inner aspect of theca interna and theca externa.
		Fish	
49	Dogfish, spiny (Squalus acanthias)	(A) Reduced to half-size when embryo 3.5-7.5 cm. (B) Advanced at 1 yr (fetus 12-20 cm); much reduced at birth.	Form mechanical support to gland cells; not glandular.
50	Ray, fiddler (Rhinobatus granulatus)	Each ovary can contain over 20 corpora in varying stages of development.	Hypertrophy and contribute to luteal tissue.
51	Shark, basking (Cetorhinus maximus)	Corpora lutea of ovulation probably formed (4-5 mm in diameter) which gradually diminish in size. Many smaller corpora formed by stresia which persist for long time.	Form thin sheath of flattened cells.

104. CHORIO-ALLANTOIC PLACENTATION: EUTHERIAN MAMMALS

Placentation of only a small percentage of total genera in each major zoological group has been studied, hence there may be many exceptions to the data in this table. Transitional types of placentation are placed with the closest major type. Developmental stages and accessory placental areas are not considered here. Data are based solely on the most prominent overall condition of the definitive chorio-allantoic placenta. Examples of main zoological groups (with common names in brackets) for each placental type are presented in Part II.

Part I: PLACENTAL TYPE AND TISSUES

	Placental Type	Maternal Tissues			Fetal Tissues	
		Endothelium	Reticulum	Epithelium	Trophoblast	Endothelium[1]
1	Epithelliochorial[2]	Present	Present	Present	Present	Present
2	Endotheliochorial	Present	Present	Absent	Present	Present
3	Hemochorial[3]	Absent	Absent	Absent	Present	Present
4	Hemoendothelial[4]	Absent	Absent[4]	Absent	Absent[4]	Present

/1/ Maternal endothelium is probably covered by a more or less delicate net of reticulum fibers functioning as a support rather than as a transmitting layer. This presumably forms the thick hyalin-like layer seen in some carnivores (raccoon). Thin and delicate reticulum probably likewise surrounds all fetal capillaries, but is infrequently stained and therefore often unnoticed. /2/ Syndesmochorial type is eliminated, and the forms (antelope, cattle, sheep) usually included are presented with the epitheliochorial group. The definitive functional portions of the so-called syndesmochorial placentas are actually epitheliochorial in nature. However, evidence has indicated that the epithelium lining the maternal crypts of some artiodactyls is of trophoblastic origin. If this is finally substantiated, then these forms may be in a sense syndesmochorial or endotheliochorial in type. /3/ Hemochorial placentas may be either villous or labyrinthine in type or transitional between these two (trabecular). /4/ Studies by cytological and histochemical methods and the electron microscope have indicated the persistence of an extremely thin layer of plasmodiotrophoblast and reticulum.

Part II. PLACENTAL TYPE AND ZOOLOGICAL GROUPS

	Epitheliochorial	Endotheliochorial	Hemochorial	Hemoendothelial
1	Insectivora (Scalopus[1]) [prairie mole]	Insectivora (Soricidae[2], Blarinae[2], Talpa[3]) [long-, short-tailed shrew, European mole]	Insectivora (most) [shrew, mole, hedgehog]	Lagomorpha [rabbit, pika]
2	Prosimii (except Tupaioidea and Tarsiiformes) [lemur[4]]	Chiroptera (Rhinolophus, Desmodus, Noctilio, Myotis, Rhinopoma, Pteropus, etc.) [bat]	Molossidae[5] (in later stages) [free-tailed bat]	Rodentia (Geomyoidea) [pocket gopher, kangaroo rat]
3	Pholidota [pangolin]	Prosimii (Tupaia) [tree shrew]	Prosimii (Tarsius) [tarsier]	
4	Cetacea [whale, dolphin, porpoise]	Edentata (Bradypus) [sloth]	Anthropoidea [man, ape, gibbon, monkey]	
5	Perissodactyla [horse]	Rodentia (Pedetes[5], Castor) [S. African jumping hare, beaver]	Edentata (Myrmecophagidae, Dasypodidae) [anteater, armadillo]	
6	Artiodactyla[6] [ox, sheep, goat, antelope, swine, giraffe, camel, hippopotamus, cattle, deer]	Carnivora[7] [racoon, dog, cat, ferret, bear, sea lion, seal]	Rodentia (most) [mouse[8], rat[8], squirrel, guinea pig, N. American porcupine]	
7		Tubulidentata [aardvark]	Hyracoidea [hyrax]	
8		Proboscidea [elephant]	Sirenia [manatee]	

/1/ Moles of the genera Parascalops, Scapanus and Neurotrichus appear similar but may be nearer the endotheliochorial condition. /2/ European and American shrews have been considered hemochorial. /3/ European mole passes through an endotheliochorial stage but reaches a hemochorial condition later. /4/ A small portion of the definitive placenta of Galago demidoffi (bush baby) is endotheliochorial. /5/ Only examples of this type thus far known among rodents. /6/ See Fn 2, Part I. /7/ See Fn 1, Part I. /8/ The late placentas of Myomorpha are apparently partly hemoendothelial.

Values in parentheses are estimates "d" of the 95% range (cf Introduction).

Part I: TIME INTERVALS BETWEEN VARIOUS PHASES

	Species	Age of Puberty	Sexual Cycle Type[1]	Sexual Cycle Duration da	Duration of Estrus	Ovulation Time[2]	Ovulation Type[3]	Ovulation Number of Eggs Released[4]	Copulation Time	Copulation Length	Sperm Transit, Vagina to Tube	Fertilization Time	Ovum Transport, Tube to Uterus da	Segmentation to Formation of Blastocoele da	Implantation or Attachment da	Gestation Period da
1	Man (Homo sapiens)	12-15.4 yr	Pe	27-28	2-8 da	15 da[5] (10-13)	S	1(BA)	Any-time	15-30 min	3 hr		3[6]	5-8[7]	8-13	267[8]
2	Armadillo, 9-banded (Dasypus novemcinctus)	1 yr	Me					1(BA)	July-Sept				In stage of monodermic blastocyst		120	120[9]
3	Bat, greater horseshoe (Rhinolophus ferrumequinum)	15 mo	Me			April	S	1(right)	Fall, spring							
4	Cat (Felis catus)	6-15 mo	Pe[11]	15-28	4 da[12], 9-10 da[13]	24-56 hr[14]	I	4-6(B)	3rd da	1-2 hr		2 da[14]	4-8		13-14?	63(52-69)
5	Cattle (Bos taurus)	6-14 mo	Pe	14-23	14-18 hr	10-15.5 hr[16]	S	1(BA)[17]	Estrus	Seconds	6 hr	Few hr[18]	3-4	8-9	40-50	281(210-335)
6	Chimpanzee (Pan satyrus)	9 yr	Pe	34-35	2-3 da	20 (16-24) da			Any-time						<10.5	(216-261)
7	Dog (Canis familiaris)	6-8 mo	Me	9	9 da[20]	1-3 da[21]	S	8-10(B)	Estrus	1-2 hr	20 min[22]	Several da[17]	6-8		13-14?	63(53-71)
8	Ferret (Mustela furo)		Me		Continuous[23]	30-36 hr[14]	I	8-9(B)	Estrus	1-3 hr	6 hr		5-6	4.5-6[7]	9-12	42
9	Fox, red, silver (Vulpes fulva)	10 mo	Me	2-4[24]	Continuous[25]	1-2 da[14]	S	3-4?(B)	Feb	15-20 min	8 min[14]	1-2 da[18]				52(49-56)
10	Goat (Capra hircus)	8 mo	Pe[11]	21	40 hr	End of estrus[7]	S	2-4(BA)	Estrus	Seconds			2.5-4	5[7]		148(135-160)
11	Guinea pig (Cavia porcellus)	55-70 da	Pe	16-19	6-11 hr	10 hr[21]	S	2-4(B)	Estrus		15 min	Few hr[18]	3.5	5-6	6	68(58-75)
12	Hamster, golden (Mesocricetus auratus)	5-8 wk	Pe	4		Early estrus	S	7(B)	Estrus	[26]			3[27]	3.25	5 or +	16(15-18)
13	Horse (Equus caballus)	1 yr	Pe[11]	10-37	4.5-9 da	24-48 hr[28]	S	1(BA)	Estrus	10-30 min	30 min		4			336(264-420)
14	Mink (Mustela vison)	8-9 mo	Pe[11]	8-9	2 da	36-50 hr[14]	I	7(B)	Estrus	0.5-2.5 hr			6-7		25	45-60
15	Monkey, rhesus (Macaca rhesus)	3 yr	Pe	28	4-6 da	(9-20) da	S	1(BA)	Any-time	[29]			3	6-8	9[14]	(146-180)
16	Mouse (Mus musculus)	35 da	Pe	4	9-20 hr[30]	2-3 hr[21]	S	6(B)	Onset of estrus		0.25-1 hr	2 hr[14]	1.45	2.5-4	4-5	19(19-21)
17	Opossum (Didelphus virginiana)	8 mo	Pe[11]	28	1-2 da	Early estrus			Estrus				2			12.5
18	Rabbit (Oryctolagus cuniculus)	5.5-8.5 mo	Pe	None[31]	1 mo or +	10 hr[14]	I	10(B)	Any-time	Seconds [32]	3-4 hr	2 hr[18]	2.5-4	3-4	7-8	31(30-35)
19	Rat (Rattus rattus)	6-11 wk	Pe	4-6	9-20 hr[33]	8-11 hr[21]	S	10(B)	1-4 hr[21]		0.5-1 hr	7-10 hr[18]	3	4.5	5-6	22
20	Sheep (Ovis aries)	7-8 mo	Pe[11]	16-21	24-48 hr	18-40 hr[21]	S	1-2(BA)[17]	Estrus	Seconds	5-6 hr	Few hr[18]	2-4	6-7	9-11	151(144-152)
21	Swine (Sus scrofa)	7(5-8) mo	Pe	21	2-3	30-48[21]	S	6-12(B)	Estrus	1-2 hr	4-6 hr		3-4	5-6	11 or -	114(101-130)

/1/ Pe = polyestrous; Me = monestrous. /2/ Values are, unless otherwise specified, time from start of sexual (estrous) cycle. /3/ I = induced ovulation; S = spontaneous ovulation. /4/ Ovaries involved in parentheses: B = both; BA = both but alternately. /5/ Before menstruation. /6/ Probably maximum time for non-segmenting ovum to reach uterine cavity. Time between fertilization and implantation, 6-7 da. /7/ Approximately. /8/ 274-280 da from first da of last menses, 267 da from ovulation. /9/ From implantation. /10/ Sperm stored in female from October to April. /11/ Seasonally. /12/ Presence of male. /13/ Absence of male. /14/ After mating. /15/ Of estrus; most receptive at this time. /16/ From end of estrus. /17/ Right ovary predominates. /18/ From ovulation. /19/ Most receptive, 15-18 da of sexual cycle. /20/ 9 da proestrus, 9 da estrus. /21/ From onset of estrus. /22/ From beginning of copulation. /23/ March to August. /24/ Period of receptivity. /25/ December to March. /26/ 8-10 P.M. /27/ Morula or blastocyst. /28/ Before end of estrus. /29/ Most receptive 2 da before ovulation. /30/ Begins 10 P.M.-1 A.M. /31/ Cycle indefinite; growth of follicles in waves of 16 da. /32/ Most receptive in estrus. /33/ Begins 4-10 PM.

Part II: MISCELLANEOUS OTHER DATA

	Species	Chromosome Number 2n	Age at First Breeding mo	Return to Estrous Cycle, Post-partum	Reproduction Interval	Optimum Breeding Period	Sperm Deposit Site	Sperm: Time of Transit[1] min	Sperm: Fertility in vivo[4] hr	Fertilization Site[3]	Placenta: Morphologic Type	Placenta: Histologic Type	Placenta: Uterine Mucosa	Follicle Size, Ovulation	Ovum Viability, Unfertilized hr
1	Man	46 ♂♀									Discoid	Hemochorial	Deciduate		
2	Cat	38	10^4	2-3 wk[5]	Varies[6]	Varies[7]		100		Oviduct[8]	Zonary to discoid	Endochorial	Deciduate		
3	Cattle	60	15-24[4]	7-105 da	13-15 mo[4]	Mid-late estrus	Anterior vagina	2.5-140	to 28	Fallopian tube	Cotyledonary	Mesocborial	Semiplacenta	10-20 mm[9]	12
4	Dog	78	6-8[10]	30-90 da[4]	5-12 mo	Estrus, every 2nd da[11]	Anterior vagina or cervix	20		Fallopian tube[12]	Zonary	Endochorial	Central band or zone	10 mm[9]	96-192
5	Goat	60	5-18[4]	Next season	Annual	Mid-late estrus	Anterior vagina			Fallopian tube	Cotyledonary	Mesochorial	Semiplacenta		
6	Guinea pig	33	1.5-2	6-8 hr	Varies[13]	Varies[13]	Uterus		22	Fallopian tube	Discoid	Hemochorial	Semiplacenta	0.8 mm	to 30
7	Horse	60	24-36	9-11 da	12-24 mo	Late estrus	Uterus	15		Diffuse	Diffuse	Epichorial	Nondeciduate	3.5-5.5 cm	
8	Mouse	40	2.5-3.5	2-4 da[14]	Varies[13]	Varies[15]	Uterus	to 15		Fallopian tube[16]	Discoid	Hemochorial	True	0.5 mm	
9	Rabbit	22	3.5-4.5[17]	Immediate	Varies[6]	May-July[18]	Anterior vagina or cervix	5-240	to 30	Fallopian tube[19]	Discoid	Hemochorial	True	1.8 mm[9]	6
10	Rat	42	1.5-2.5	2-4 da[14]	Varies[13]	Varies[15]	Uterus	to 15	14	Fallopian tube[16]	Discoid	Hemochorial	True	0.9 mm	16-17[20]
11	Sheep	54	6-18[4]	Next season	Annual	Mid-late estrus	Anterior vagina	10-30		Fallopian tube	Cotyledonary	Mesochorial	Semiplacenta	15-19 mm	12-24
12	Swine	40	5-10[4]	3-4 da[4, 5]	5-12 mo[4]	Late mid-estrus	Cervix			Fallopian tube	Diffuse	Epichorial	Nondeciduate	7-10 mm	to 12

/1/ From cervix to ovarian end of oviduct (Fallopian tube). /2/ In female genital tract. /3/ Implantation site: uterine horn. /4/ Variable. /5/ After weaning. /6/ May reproduce continually. /7/ Geographically influenced. /8/ Upper third. /9/ Diameter. /10/ Or first estrus. /11/ Also anytime after 4th da of estrus. /12/ Probably middle half. /13/ With strain or management. /14/ After removal of litter. /15/ With strain. /16/ Ovarian end. /17/ Fall born; spring born, 6.5-7.5 mo. /18/ In USA. /19/ Upper half. /20/ In oviduct.

Part III: SURVIVAL IN VITRO: SPERM

	Species	Method of Collecting Sgmen[1]	Diluent: Ratio	Diluent: Substance	Sperm-Extender Ratio	Cooling °C/min	Storage Temperature °C	Storage Time[2]	Insemination: Site	Insemination: Time	Insemination: Volume cc
1	Cattle	A	1:1	2.9% Na citrate dihydrate; egg yolk[3] + 0.3% sulfanilamide + 500 µg/ml dihydrostreptomycin.	<1:200 (>11,000,000 sperm/ml)	1	5	<48	Cervix or uterus	End of estrus	1-2
2	Dog	A or M	←	None	→			0	Cervix[4]	11-13 da[5]	1-10
3	Horse	A	5:1	5% glucose in H_2O; egg yolk.	1:1	1	5	<40	Uterus	12-20 hr[6]	10-50
4	Mouse	S	←	Locke's solution	→			0	Uterus[7]	1.5-2.5 hr[8]	0.02-0.10
5	Rabbit	A	←	Krebs' solution[9]	→	1:4		0	Anterior of vagina	After mating[10]	0.25-1.0
6	Rat	S	←	Locke's solution [11]	→			0	Cervix[12]	Estrus	0.1-0.2[13]
7	Sheep, goat	A	←	As cattle[14]	→	<1:11 (>11,000,000 sperm/ml)	1	5	<48	Cervix	Last half of estrus	0.1-0.2
8	Swine	A	←	Krebs' solution	→	1:2.5[15]; 1:5[16]		0	Cervix or uterus[4]	12-23 hr[6]	50[15], 250[16]

/1/ A-artificial vagina; M-manual manipulation; S-stripping sperm from vas deferens. /2/ 0-use immediately without storage. /3/ Fresh. /4/ Place cotton plug in vagina after insemination. /5/ After first bleeding. /6/ After onset of estrus. /7/ By laparotomy, female under ether anesthesia. /8/ After mating with vasectomized male. /9/ Modified. /10/ With vasectomized buck. /11/ Dilution must produce thick, viscid suspension. /12/ Female anesthetized; plug vagina with cotton dipped into secretions from seminal vesicles and coagulating fluid. /13/ Into each cervical canal. /14/ Necessity of bacterial antigens unknown. /15/ Gilts. /16/ Sows.

	Test[1]	Test Animals	Duration of Test	Source of Test Material	Substance Tested For	Earliest Positive Indications	Positive Diagnostic Findings	Accuracy[2] % +	Accuracy[2] % -	Remarks
1	Aschheim-Zondek	3-4 female mice, 3-4 wk old; 6-8 g	96-100 hr	1st morning urine.	Chorionic gonadotropin.	10 da-2 wk after 1st missed menses.	Hemorrhagic follicles on ovary; corpora lutea containing entrapped ovum.	6	3.5	Sensitive; accurate; reliable; expensive(?); time consuming; occasional false positives caused by maturation of mouse ovaries[3].
2	Ovarian hyperemia[4]	2-3 immature female rats; 45-60 g	1-24 hr	1st morning urine.	Chorionic gonadotropin.	1-2 wk after 1st missed menses.	Ovary usually enlarged; diffuse reddening or many distinct red spots.	1-2	10	Difficult end point; false negatives are common; very rapid test[4].
3	Friedman	Mature female rabbits, 3-4 lb; previously isolated 4 wk	18-24 hr	1st morning urine.	Chorionic gonadotropn.	1-2 wk after 1st missed menses.	Early corpora lutea; ova can be washed from tubes; hemorrhagic follicles.	1	2-3	Animals need not be sacrificed; rapid but expensive test.
4	Galli-Mainini	Male frog (Rana pipiens) or male toad (Bufo arenarum)	10-120 min	1st morning urine, or blood serum.	Chorionic gonadotrophin.	2 wk after 1st missed menses.	Spermatozoa in urine collected from cloacal region; examined microscopically pre- and post-injection.	0(?)[5]	2.5	Less sensitive in summer months, in early pregnancy, presence of jaundice; inexpensive; animals need not be sacrificed.
5	Hogben	Segregated female S. African clawed "toad" (Xenopus laevis)	5-18 hr	1st morning urine.	Chorionic gonadotropin.	1-2 wk after 1st missed menses.	Presence of egg mass on floor of container housing toad.	6[6]	0.2[6]	Simple end point; animals need not be sacrificed and may be used repeatedly; rapid, accurate test.
6	Delfs	Immature female rats, 21-23 da old; 34-42 g	72-96 hr	Blood serum; pooled urine.	Total chorionic gonadotropn.	After 1st missed menses.	Uterine weight increase (vs controls) determined at 72 hr post-injection.	17	24	Used primarily as quantitative assay fin trained hands) of chorionic gonadotropin levels.
7	Guterman		3 hr	1st morning urine.	Pregnanediol.	At time of 1st missed menses.	Development of color complex; orange to deep orange-brown with sulfuric acid.	7-8	8-9	Valuable(?) in abortion and hydatidiform mole; false positives: (a) late in menstrual cycle; (b) progesterone treatment; (c) luteal cysts; (d) pseudocyesis.
8	Kapeller-Adler		½ hr	1st morning urine.	Histidine.	1st wk after missed menses.	Colorimetric qualitative and quantitative.	10	11	Simple; inexpensive; urine constituents after color reaction as do catabolic products in urine. Non-specific(?).
9	Visscher-Bowman		½ hr	1st morning urine.	Chorionic gonadotropin(?).	After 1st missed menses.	Russet color reaction with flocculation.	8	11	Simple; inexpensive; false positives: (a) in fever; (b) excess of catabolic products in urine. Non-specific(?).
10	Gilfillen-Gregg		½-1 hr	Injection of chorionic gonadotropn.		After 1st missed menses.	No skin reaction in pregnancy, i.e., hypoallergy to chorionic gonadotropin.	22	13	Simple, but interpretation difficult; limited in Negroes.
11	Basal temperature deviations			Temperature, rectal or oral.		Ante- and post-conception observation.	Luteal phase temperature sustained for more than 16 da (preceded by a characteristic biphasic curve)[7].	1	0(?)	Early diagnosis of pregnancy; false positives: (a) mild febrile illness; (b) changes in climate; (c) pseudocyesis; (d) persistent corpus luteum.
12	Schwartz		3-7 da	Estrone and progesterone injections daily, or oral estrogen and progesterone.		At time of 1st missed menses.	Continued amenorrhea with otherwise normal menstrual cycles and no demonstrable pelvic disease.	High degree of accuracy		Simple; inexpensive(?); false positives: (a) ectopic pregnancy when patient is spotting; (b) amenorrhea of more than 6 mo duration; (c) pseudocyesis; (d) persistent corpus luteum.
13	Richardson		½ hr	1st morning urine; blood serum or saliva.	Estrogens.	At time of 1st missed menses.	Development of color complex with phenylhydrazone, phenylsulfone.	2	2	False positives in hyperestronism; ovarian tumor; of value in diagnosis of hydatidform mole. Non-specificity(?) can cause false reactions.
14	Colostrum "Q"		1 hr	Colostrum.	Immune reaction to protein of colostrum.	2 wk after 1st missed menses.	Pregnancy: disappearance of original wheal in 30 min. Non-pregnant: enlargement of wheal 2-3 times with red areola.	5	2	Unreliable in hyperallergic individuals and Negroes; false positives in menopause and during menstrual period.

/1/ Tests 1-6, 9(?) depend on physiological reactions of test animal to chorionic gonadotropin present in pregnancy urine. /2/ Claimed. /3/ False positives may also occur during depression of ovarian function (e.g., menopause). /4/ A recent modification of this test involves the addition of a pituitary synergist; the duration of the test is reduced to 1-3 hr, false positives to 0.1%, false negatives to 2%, and the end point is much more definite. /5/ False positives have been reported, and a percentage of false negatives as high as 16. /6/ False positives of 1%, and false negatives up to 4% have been reported. /7/ The luteal phase is partially biphasic.

107. LIFE CYCLE AND SEXUAL MECHANISM: ALGAE AND FUNGI

Terms followed by an asterisk (*) are defined in the Glossary Part VI.

Part I: LIFE CYCLE, SEXUALITY, AND SEXUAL MECHANISM: ALGAE

Data in columns B and D refer to the corresponding patterns presented in Parts III and V. In column C, M = monoecious*, D = dioecious*.

	Species	Life Cycle of Type	Pattern of Sexuality	Sexual Mechanism and Development
	(A)	(B)	(C)	(D)
	Chlorophyta			
1	Chlamydomonas paupera	B	M	3-5-10
2	C. eugametos	B	D	3-5-10
3	Volvox aureus	B	D^1	3-7-9-10
4	V. globator	B	M	3-7-9-10
5	Tetraspora lubrica	B	D	3-7-9-10
6	Sphaerocystis schroeterii	A		
7	Chlorella vulgaris	A		
8	Chlorococcum humicolor	B	M	3-7-9-10
9	Dictyosphaerium indicum	B	D	3-7-9-10
10	Hydrodictyon reticulatum	B	M	3-7-9-10
11	Protosiphon botryoides	B	M	3-7-9-10
12	Chlorochytridium lemnae	G	?	1-10
13	Ulothrix zonata	B	M	3-7-9-10
14	U. zonata	B	D	3-7-9-10
15	Ulva lactuca	F	D	3-7-9-10
16	Cladophora suhrina	F	D	3-7-9-10
17	C. glomerata	G	M	1-10
18	Protococcus viridis	A		
19	Draparnaldiopsis indica	F	D	3-7-9-10
20	Coleochaete pulvinata	B	M	3-8-9-10
21	C. scutata	B	D	3-8-9-10
22	Oedogonium kurzii	B	M	3-7-9-10
23	O. grande	B	D	3-7-9-10
24	O. crassiusculum	B	M	See Fn 2
25	O. spirale	B	D	See Fn 2
26	Spirogyra setiformis	B	D	(3)-7-12^3
27	S. granulata	B	M	(3)-7-12
28	Dasycladus clavaeformis	G	D^4	1-10
29	Bryopsis pulvinata	G	M	1-10
30	Chara fraglis	B	M	3-8-9-10
31	Nitella capitata	B	D	3-8-9-10
	Chrysophyta			
32	Xanthophyceae, most spp	A		
33	Botrydium granulatum	B	M & D^4	3-7-9-10
34	Vaucheria sessilis	B	M	3-8-9-10
35	V. dichotoma	B	D	3-8-9-10
36	Chrysophyceae, most spp	A		
37	Ochrosphaera neopolitana	B	M	3-7-9-10
38	Centrales, most spp	A		
39	Cyclotella meneghiniana	G	M	1-10
40	Amphora normani	G	M	1-10
41	Rhopalodia gibba	G	D	1-10
	Pyrrophyta			
42	Peridinium wisconsinensis	A		
	Phaeophyta			
43	Fylaiella rupincola	A		
44	Ectocarpus siliculosus	F	D	3-8-9-10
45	Sphacelaria bipinnata	F	M	3-8-9-10
46	Lamanaria saccharina	F	D	3-8-9-10
47	Pelvetia fastigiata	G^5	M	1-10
48	Fucus vesiculosus	G^5	D	1-10
	Rhodophyta			
49	Rhodospora	A		
50	Porphyra elongata	B	M	3-7-9-11
51	P. dentata	B	D	3-7-9-11
52	Batrachospermum monilliforme	B	M	3-8-9-11
53	B. elegans	B	D	3-8-9-11
54	Polysiphonia violacea	F	D	3-8-9-11
55	Griffithsia barbata	F	M	3-8-9-11
	Cyanophyta			
56	All species	A		

/1/ Dioecism is not absolute; colonies with both eggs and sperm have been reported. /2/ Species produces, inlieu of antheridia, specialized swarmers (androspores) which come to rest upon or near the oögonium and develop into dwarf male plants, each of which bears 1 to 4 antheridia. /3/ The fusing elements of the species are commonly termed gametes but are here considered gametangia because of the low degree of morphological differentiation. The copulatory process in these forms approaches somatic copulation, the sexual fusion of vegetative cells common in higher fungi. /4/ Species includes monoecious and dioecious varieties. /5/ Species commonly with 2 haploid nuclear generations in the oögonium and 4 in the antheridium.

Part II: LIFE CYCLE, SEXUALITY, AND SEXUAL MECHANISM: FUNGI

Data in columns B, C, D refer to the corresponding patterns presented in Parts III, IV, V.

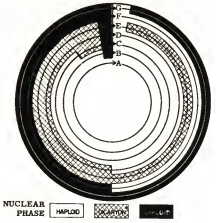
	Species	Life Cycle of Type	Pattern of Sexuality	Sexual Mechanism and Development
	(A)	(B)	(C)	(D)
	Myxomycetes			
1	Labyrinthula macrocystis	A		
2	Dictyostelium discoideum	B	O	3-5-10
3	Physarum polycephalum	G^1	?	2-10
4	Plasmodiophora brassica	F	?	3-7-9-10
	Phycomycetes			
5	Olpidium viciae	B	?	3-7-9-10
6	Polyphagus euglenae	B	I	3-7-12
7	Allomyces javanicus	F	O	3-8-9-10
8	A. cystogenus	G^2	?	1-10
9	A. anomalus	A		
10	Blastocladiella variabilis	F	I	3-7-9-10
11	Monoblepharia sphaerica	B	O	3-8-9-10
12	Myxochytrium vermicola	B	O	3-7-12
13	Lagenidium rabenhorstii	B	I^3	3-7-12
14	Achlya ambisexualis	B	II	3-8-9-11
15	A. americana	B	O	3-8-9-11
16	Sapromyces reinschii	B	II	3-8-9-11
17	S. andrognous	B	O	3-8-9-11
18	Phytophthora omnivora	B	II	3-8-9-11
19	P. erythroseptica	B	O	3-8-9-11
20	Phycomyces blakesleeanus	B	I	3-8-12
21	Sporodinia grandis	B	O	3-8-12
22	Basidiobolus ranarum	B	O	3-7-12
23	Entomophthora aepulchralis	B	O	3-8-12
24	Ascomycetes			
25	Eremascus fertilis	B	O	3-8-12
26	Schizosaccharomyces octosporus	B	O	3-5-10
27	Zygosaccharomyces lactis	B	V	3-5-10
28	Saccharomycodes ludwigii	G	V	2-10
29	Saccharomyces ellipsoideus	G^4	V^5	2-10
30	S. fraglis	G	O	2-10
31	Candida albicans	A		
32	Taphrina epiphylla	D-E	V	3-5-10-13
33	Aspergillus niger	C	O	3-8-12-13
34	A. repens	C	O	3-8-12-13
	Ascomycetes (concluded)			
35	Penicillium luteum	C	O	3-8-12-13
36	Sphaerotheca fuliginea	C^6	O	3-8-12-13
37	Erysiphe cichoracearum	C	I/III^3	3-8-12-13
38	Neurospora sitophila	C	III	3-8-9-11-13
39	Pleurage anserina	C	III^7	3-8-9-11-13
40	Sordaria fimicola	C	O	3-8-12-13
41	Venturia inequalis	C	I/III	3-8-12-13
42	Glomerella cingulata	C	O^8	3-8-12-13
43	Mycosphaerella tulipifera	C	?	3-8-9-11-13
44	Hypomyces solani f. cucurbitae	C	IV	3-8-9-11-13
45	Claviceps purpurea	C	?	3-8-12-13
46	Stigmatomyces baeri	C	O	3-8-9-11-13
47	Amorphomyces falagriae	C	I	3-8-9-11-13
48	Pyronema confluens	C	O	3-8-12-13
49	Sclerotinia gladioli	C	III	3-8-9-11-13
50	Ascobolus magnificus	C	III	3-8-12-13
	Basidiomycetes			
51	Stereum hirsutum	D	O	3-6-13
52	Fomes pinicola	D	V^9	3-6-13
53	Aleurodiscus polygonius	D	VI^9	3-6-13
54	A. canadensis	E	O^7, 10	(4)-13
55	Coprinus stercorarius	D	O	3-6-13
56	C. comatus	D	V^9	3-6-13
57	Schizophyllum commune	D	VI^9	3-6-13
58	Galera pubescens f. bispora	E	O^7, 11	(4)-13
59	Cystlus striatus	D	VI^9	3-6-13
60	Exidia glandulosa	D	V^9	3-6-13
61	Colocera cornes	E	O^7, 11	(4)-13
62	Auricularia auricula-judae	D	V^9	3-6-13
63	Phleogena fagina	D	O	3-6-13
64	Puccinia graminis	D	III	3-8-9-11-13
				or 3-6-13
65	P. xanthi	D	O	3-6-13
66	Graphiola phoenicis	C	O	3-6-13
67	Ustilago violacea	E	IV	4-13 or 3-6-13

/1/ Haploid phase may consist of one to few nuclear generation. /2/ One mitotic division of haploid nucleus interposed between meiosis and gametic fusion. /3/ Type of heterothallism unknown. /4/ Haploid phase may vary in duration from a single nuclear generation, i.e., in the fusion of ascospores, to many generations involving an extended haploid vegetative stage. /5/ Genetic (compatibility) factors governing mating type may be relatively unstable, a condition termed "partial heterothallism." /6/ Dicaryon may be limited to a single cell, the sacal initial. /7/ Two nuclei of opposed compatibilities regularly included in the ascospore, which germinates to produce a self-fertile, heterokaryotic mycelium, a condition termed "secondary homothallism." /8/ Basically homothallic but may be "partial heterothallic." /9/ Mating behavior is determined by multiple alleiomorphs (incompatibility factors at one locus, V (bipolar sexuality), or at two loci, VI (tetrapolar sexuality). /10/ Genetically bipolar and secondarily homothallic. /11/ Secondarily homothallic.

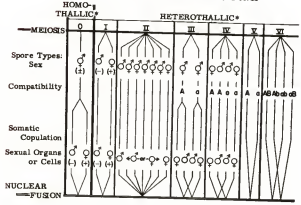
107. LIFE CYCLE AND SEXUAL MECHANISM: ALGAE AND FUNGI (Concluded)

Part III: TYPES OF LIFE CYCLES: NUCLEAR PHASE

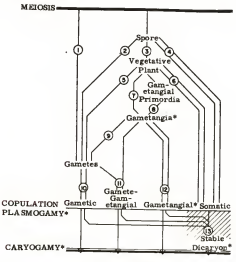
Schematic representation of the occurrence and relative duration of the 3 nuclear phases in algae and fungi.



Part IV: PATTERNS OF SEXUALITY: FUNGI



Part V: SEXUAL MECHANISMS AND DEVELOPMENT PATTERNS: ALGAE AND FUNGI



Part VI: GLOSSARY

Caryogamy: Sexual fusion of 2 nuclei. Dicaryon: Condition of cells, containing 2 nuclei brought together usually by a sexual process and which divide in unison. Dioecious: Individual plants are unisexual. Gametangium: A cell or organ in which gametes are formed. Sometimes gamete formation is suppressed and a gametangium itself may function in copulation. Heterothallism: Condition in which 2 self-sterile strains are necessary to form the sexual stage. Homothallism: Condition in which the organism is sexually self-fertile. Monoecious: Individual plants produce both kinds of gametes or sex organs. Plasmogamy: Sexual fusion of 2 cells without fusion of nuclei.

108. HETEROTHALLISM AND HOMOTHALLISM: FUNGI

MH=morphological heterothallism; PH=physiological heterothallism; multiple factors: bsbipolar, tetetrapolar, m=evidence for multiple factors; H=homothallism; H2=secondary homothallism. Relative degree of maleness and femaleness, as well as detectable but not absolute heterothallism, is indicated by (rel). Available evidence implies that organisms 1-83, indicated as PH, have only 2 mating types in a population; the Basidiomycetes, excluding most rusts and smuts, have multiple mating types. Morphological heterothallism and secondary homothallism are categories as defined by Whitehouse, H. L. K., in Biol. Rev., 24: 411, 1949.

	Species	Type		Species	Type		Species	Type
	Phycomycetes: general			Basidiomycetes: Tremellales		144	Hebeloma circinans,	
1	Achlya ambisexualis	H(rel)	71	Auricularia auricula-judae	PHbm		H. truncatum	PHt
2	A. regularis	MH	72	Decryomyces deliquescens	Phb	145	Hydnum auriscalpium	PHt
3	Blastocladiella cystogena,		73	Exidia glandulosa	PHbm	146	Hypholoma spp	PHt
	B. stubenii	PH	74	E. nucleata	PH	147	Inocybe tricholoma	PHt
4	Dictyuchus spp	MH	75	E. recesa, E. saccharina	PHbm	148	Irpex fuscoviolaceus,	
5	Peronospora parasitica	H(rel)	76	Femsjonia luteo-alba	Phb		L. pendulus	PHt
6	Phytophthora parasitica	MH(rel)	77	Pilacre fagines	PHb	149	Lentinus ursinus	PHt
7	Sapromyces reinschii	MH(rel)		Basidiomycetes: Ustilaginales		150	Lenzites betulina	PHtm
8	Zoophagus insidians	MH	78	Sphacelotheca spp	PH	151	L. malacensis	PH
	Phycomycetes: Mucorales		79	Tilletia caries, T. foetida	PH	152	L. saepiaria	PHb
9	Absidia spp	PH	80	Ustilago spp	PH	153	L. tigurina	PHt
10	Blakesiea trispora	PH		Basidiomycetes: Uredinales		154	Leptoporus adustus	PHb
11	Chaetocladium brefeldii	PH	81	Cronartium ribicola	PH	155	L. imberbis, L. ostreiformis	PHb
12	Choanephora conjuncta	PH	82	Gymnosporangium globosum	PH	156	Leucoporus arcularius,	
13	C. cucurbitarum	PH	83	G. harasenum	PH		L. brumalis	PHt
14	Circinella spinosa, C. umbellata	PH	84	G. juniperi-virginianae	PHb	157	Marasmius cohaereus	PHb
15	Cunninghamella terrholletiae	PH	85	Melampsora lini	PHb	158	M. elongatipes	PHt
16	C. echinata, C. elegans	PH	86	Phragmidium speciosum	PHb	159	M. oreades	PH
17	Helicostylum piriforme	PH	87	Puccinia spp	PHb	160	M. personatus	PHt
18	Mucor spp	PH	88	Uromyces appendiculatus	PHb	161	Marasmius spp	PHb
19	Parasitella simplex	PH	89	U. vignae	PHb	162	Merulius rufus	PHb
20	Phycomyces blakesleeanus,			Basidiomycetes: Agaricales		163	Mycena spp	H
	P. nitens	PH	90	Agaricus campestris	H	164	Mycena spp	PHt
21	Rhizopus nigricans	PH	91	Agrocybe dura	PHt	165	Odontia bicolor, O. separans	PH
22	Syncephalastrum racemosum	PH	92	A. pediales,		166	O. setigera	PHb
	Ascomycetes: general			A. semiorbicularis	PHb	167	O. sudans	PH
23	Ascobolus spp	PH	93	A. sphaleromorpha	PH	168	Omphalia mairei	PH
24	Ascophanus granulatus	PH	94	Armillaria mucida	PHt	169	O. maura	PHt
25	Aspergillus fischeri	H	95	Clitocybe aurantiaca	PHt	170	O. maura alba	PHb
26	A. glaucus, A. repens	H	96	C. cyathiformis	PHb	171	Panaeolina foenisecii	PHb
27	Bombardia lunata	PH	97	C. dicolor, C. gallinaces,		172	Panaeolus acuminatus	PHb
28	Ceratostomella spp	PH		C. gigantea	PHt	173	P. campanulatus	PHt
29	Cercospora caudae-suis	H	98	C. radicellata	PH	174	P. fimicola	PH
30	Chaetomium spp	H	99	Collybia spp	PHt	175	Panellus mitis	PHt
31	Diaporthe phaseolorum	PH	100	Conocybe pubescens	PHt, H2	176	Panus stipticus	PHtm
32	Endoconidiophora fagearum	PH	101	C. spicula	PHt	177	Peniophora spp	PHb
33	Erysiphe cichoracearum	PH	102	Coprinus spp	PHb	178	P. candida	PH
34	Fimetaria fimicola	H	103	Coprinus spp	PHt	179	P. ciliata	PH
35	Gelasinospora tetrasperma	H	104	C. amphithallus	PHt[1]	180	P. cinerea, P. farinosa	PH
36	Gibberella moniliformis	PH	105	C. angulatus, C. callinus	PHtm	181	Phlebia auranticaea	PHb
37	Monascus spp	H	106	C. bisporus	H	182	Pholiota adiposa, P. aurivella	PHb
38	Neurospora crassa	PH	107	C. comatus	PHbm	183	P. cylindracea, P. mutabilis	PHt
39	N. tetrasperma	H2	108	C. hiascens, C. meveus	PHtm	184	Pleurotus spp	PHt
40	Patella melaloma	PH	109	C. pellucidus	H	185	Polyporus anceps	PHbm
41	Penicillium spp	H	110	C. sasii	PHb[1]	186	P. borealis	PH
42	Pleurage spp	H	111	C. sclerocystidiosus	PHtm	187	P. tuckahoe	PH
43	P. anserina	H2	112	C. silvaticus	PH	188	Poria microspora	PHbm
44	Podospora minuta	PH, H2	113	C. stellatus	H	189	P. mucida	PHt
45	Sclerotinia sclerotiorum	H	114	Coriolus abietinus	PHtm	190	Psathyrella spp	PHt
46	Stromatinia gladioli	PH	115	C. hirsutus	PHb	191	Pseudocoprinus disseminatus	PHbm
47	S. narcissi	MH	116	C. versicolor	PHt	192	P. impatiens	PHtm
48	Taphrina deformans	H	117	Cornirellus shutake	PHb	193	Psilocybe foenisecii	PHt
49	T. epiphylla, T. klebahni	PH	118	Corticium bombycinum	PHt	194	P. subviscida	PH
50	Venturia inaequalis, V. pirina	PH	119	C. calceum	PH	195	Radulum orbiculare	PHbm
	Ascomycetes: Laboulbeniaceae		120	C. conigenum	PHb	196	Rhodopexillus nudus	PH
51	Amorphomyces spp	MH	121	C. coronilla	PHbt, H	197	Schizophyllum commune	PHtm
52	Apotomyces laboulbenioides	MH	122	C. effuscatum	PHtm	198	Solenia anomala	PHb
53	Aporomyces subulatus	MH	123	C. evolvens	PHt	199	Sprassis crispa	PHb
54	A. trinitatis, A. uniflagellatus	MH	124	C. hydnans	PH	200	Stereum chilletii	PHt
55	Chitonomyces, all species	MH	125	C. incrustans	PHb	201	S. murrayi	PH
56	Dicrandromyces terminalis	MH	126	C. laeve	PH	202	S. rufum	PHt
57	Dimeromyces, all species	MH	127	C. polygonium	PHt	203	S. spadiceum	PHb
58	Dimorphomyces denticatus,		128	C. porosum, C. radiosum	PH	204	S. sanguinolentum	H
	D. muticus	MH	129	C. serum	PHt	205	Stropharia semiglobata	PHbm
59	Diolcomyces spp	MH	130	Cortinellus berkeleyana	PHt	206	Trametes cinnabarina	PHt
60	Eudimeromyces, all species	MH	131	Crinipellis stipitarius	PHt	207	T. suaveolens	PHtm
61	Herpomyces spp	MH	132	Cytidia flocculenta, C. salicina	PHb	208	Typhula erythropus	PHt
62	Nanomyces appendiculatus	MH	133	Deconica atrorufal,		209	T. gyrans, T. trifolii	PH
63	N. fijianus,			D. inquilina	PHt	210	Xeromphalina campanella	PHt
	N. perpendicularis	MH	134	D. coprophila, D. crobula	PHb		Gasteromycetes	
64	Rhinopodomyces merogatae	MH	135	Drosophila spp	PH	211	Crucibulum vulgare	PHtm
65	Tetrandromyces brachidae	MH	136	D. semivestita	PHb	212	Cyathus olla, C. stercoreus	PH
66	Triandromyces bottegoi	MH	137	Flammula carbonaria	PHt	213	C. striatus	PHtm
	Ascomycetes: Yeasts		138	F. conissans, F. lenta	PHt	214	C. vernicosus	PH
67	Dematium chodati	PH	139	Fomes fraxineus	PHb	215	Nidula candida	PH
68	Endomycopsis ohmeri	PH	140	F. ignarius	PHtm	216	Nidularia farcta	PH
69	Saccharomyces cerevisiae,		141	F. pinicola, F. roseus	PHbm	217	N. pisiformis	PH
	S. ludwigii	PH	142	Galera sphagnorum	PHt	218	Scleroderma aurantium	PH
70	Zygosaccharomyces lactis	PH	143	Gloeocystidium roseo-cremum	PHb	219	Sphaerobolus stellatus	PHt

/1/ Amphithallic, i.e. both hetero- and homothallic spores occur in the same fruit.

109. BREEDING SYSTEMS: PLANTS

Systems listed below indicate the usual classification of breeding. Where variability exists within a species, the predominating system is enclosed in parentheses.
SC-S = species predominately self-compatible, no imbreeding degeneration; SC = self-compatible, intermediate, with perhaps a predominance of outcrossing; SC-M = self-compatible, monoecious, therefore rarely selfed under open pollination; SI = self-incompatible; D = dioecious; A = apomictic.

	Species	System[1]
	Monocotyledones	
	Pandanaceae	
1	Screw-pine (Pandanus tectorius)	D
2	Screw-pine (P. utilis)	D
	Gramineae	
3	Barley (Hordeum sativum)	SC-S
4	Buffalo grass (Buchloe dactyloides)	D
5	Corn (Zea mays)	SC-M
6	Fescue (Festuca pratensis)	SI
7	Millet (Panicum miliaceum)	SC-S
8	Oat (Avena sativa)	SC-S
9	Orchardgrass (Dactylis glomerata)	SI
10	Rice (Oryza sativa)	SC-S
11	Rye (Secale cereale)	SI
12	Ryegrass (Lolium perenne)	SI
13	Sorghum (Sorghum vulgare)	SC-S
14	Sugar cane (Saccharum officinarum)	SI
15	Teosinte (Euchlaena mexicana)	SC-M
16	Timothy (Phleum pratense)	SI
17	Wheat (Triticum spp)	SC-S
18	Wildrice (Zizania aquatica)	SC-M
	Cyperaceae	
19	Sedge (Cyperus papyrus)	SC
20	Sedge (C. tegetiformis)	SC
	Palmaceae	
21	Date (Phoenix dactylifera)	D
22	Oil palm (Elaeis guineensis)	SC
23	Palmetto (Sabal palmetto)	SC
24	Palmyra palm (Borassus flabellifer)	D
25	Wine palm (Caryota urens)	SC
	Cyclanthaceae	
26	Carludovica (Carludovica palmata)	SI
	Araceae	
27	Sweet flag (Acorus calamus)	SI
	Bromeliaceae	
28	Pineapple (Ananas sativus)	SI
	Juncaceae	
29	Rush (Juncus effusus)	SC
	Liliaceae	
30	Aloe (Aloe spp)	SI
31	Asparagus (Asparagus officinalis)	D
32	Chives (Allium schoenoprasum)	SI
33	Garlic (A. sativum)	A
34	Hyacinth (Hyacinthus orientalis)	SC
35	Lily (Lilium candidum)	
36	Lily (L. regale)	(SC)
37	Onion (Allium cepa)	SC[2]
38	Shallot (A. ascalonicum)	SC
39	Smilax (Smilax officinalis)	D
40	Tulip (Tulipa spp)	SC
41	Yucca (Yucca spp)	SI
	Amaryllidaceae	
42	Agave (Agave spp)	SI
43	Narcissus (Narcissus spp)	SI
	Iridaceae	
44	Crocus (Crocus spp)	SC
45	Iris (Iris spp)	SC
	Dioscoreaceae	
46	Yam (Dioscorea alata)	SC
	Musaceae	
47	Abaca (Musa textilia)	SC
48	Plantain (M. paradisiaca)	SC
	Zingiberaceae	
49	Ginger (Zingiber officinale)	SI
	Cannaceae	
50	Canna (Canna edulis)	SC
	Marantaceae	
51	Arrowroot (Maranta arundinacea)	SC
	Dicotyledones	
	Piperaceae	
52	Pepper (Piper spp)	D
	Salicaceae	
53	Poplar (Populus spp)	D
54	Willow (Salix spp)	D
	Myricaceae	
55	Wax myrtle (Myrica cerifera)	D
	Juglandaceae	
56	Hickory (Carya spp)	SC-M
57	Walnut (Juglans spp)	SC-M
	Betulaceae	
58	Alder (Alnus spp)	SC-M
59	Birch (Betula spp)	SC-M

	Species	System[1]
	Dicotyledones (continued)	
	Betulaceae (concluded)	
60	Filbert (Corylus spp)	SC-M
61	Hophornbeam(Ostrya virginiana)	SC-M
62	Hornbeam (Carpinus spp)	SC-M
	Fagaceae	
63	Beech (Fagus spp)	SC-M
64	Chestnut (Castanea spp)	SC-M
65	Oak (Quercus spp)	SC-M
	Ulmaceae	
66	Elm (Ulmus spp)	SC-M
67	Hackberry (Celtis occidentalis)	SC
	Moraceae	
68	Breadfruit (Artocarpus incisa)	SC
69	Broussonetia (Broussonetia papyrifera)	D
70	Castillo (Castillos elastica)	SC
71	Chlorophora (Chlorophora tinctoria)	D
72	Ficus (Ficus, most spp)	SC
73	Fig (F. carica)	D
74	Hemp (Cannabis sativa)	D
75	Hop (Humulus lupulus)	D
76	Mulberry (Morus alba)	D
77	Mulberry (M. nigra)	D
78	Osage-orange (Maclura pomifera)	D
	Proteaceae	
79	Silk oak (Grevillea robusta)	SC
	Polygonaceae	
80	Buckwheat(Fagopyrum esculentum)	SI[3]
81	Sea-grape (Coccoloba uvifera)	SC
	Chenopodiaceae	
82	Beet (Beta vulgaris)	SI
83	Spinach (Spinacia oleracea)	D
	Caryophyllaceae	
84	Soapwort(Saponaria officinalis)	SC
85	Carnation (Dianthus caryophyllus)	SC
	Berberidaceae	
86	May apple (Podophyllum peltatum)	SC
	Annonaceae	
87	Custard-apple (Annona spp)	SC
	Myristicaceae	
88	Nutmeg (Myristica fragrans)	D
	Lauraceae	
89	Avocado(Persea gratissima)	SC
90	Beberru wood (Nectandra rodioei)	SC
91	Cinnamon (Cinnamomum spp)	SC
92	Sassafras (Sassafras albidum)	D
93	Sweet bay (Laurus nobilis)	D
	Papaveraceae	
94	Poppy (Papaver somniferum)	SC
95	Poppy,prickly (Argemone mexicana)	SC
	Capparidaceae	
96	Caper-bush (Capparis spinosa)	SC
	Cruciferae	
97	Cabbage (Brassica oleracea)	(SI)
98	Horse-radish (Radicula armorscia)	SI
99	Mustard (Brassica nigra)	SI
100	Mustard (B. juncea)	SC
101	Pepper-grass (Lepidium sativum)	SC-S
102	Radish (Raphanus sativus)	SI
103	Rape (Brassica napus)	SC
104	Roquette (Eruca sativa)	SI
105	Rutabaga (Brassica campestris)	SI
106	Sea-kale (Cakile maritima)	SI
107	Stock (Matthiola incana)	SC
108	Wallflower (Cheiranthus cheiri)	
109	Water-cress (Radicula nasturtium-aquaticum)	SC
	Resedaceae	
110	Dyer's-weed (Reseda luteola)	SC
111	Mignonette (R. odorata)	SI
	Saxifragaceae	
112	Currant,gooseberry (Ribes spp)	SC
	Hamamelidaceae	
113	Witch-hazel (Hamamelis virginiana)	SC
	Platanaceae	
114	Sycamore (Platanus occidentalis)	SC-M
115	Sycamore (P. orientalis)	SC-M
	Rosaceae	
116	Almond (Prunus communis)	(SI)
117	Apple (Pyrus malus)	SI
118	Apricot (Prunus armeniaca)	SC

	Species	System[1]
	Dicotyledones (continued)	
	Rosaceae (concluded)	
119	Cherry (Prunus avium)	SI
120	Cherry (P. cerasus)	SC
121	Loquat (Eriobotrya japonica)	SC
122	Medlar (Mespilus germanica)	SC
123	Peach (Prunus persica)	SC
124	Pear (Pyrus communis)	SI
125	Plum (Prunus americana)	SI
126	Plum (P. salicina)	SI
127	Quince (Cydonia oblonga)	SC
128	Rose (Rosa, most spp)	SC
129	Rose (R. rugosa)	SI
130	Rubus (Rubus, most spp)	SC
131	Rubus (R. calvatus)	A
132	Rubus (R. nitidioides)	A
133	Rubus (R. thyrsiger)	A
134	Strawberry (Fragaria chiloensis)	D
135	Strawberry (F. vesca)	D
136	Strawberry (F. virginiana)	D
137	Strawberry (F. viridis)	SI
	Leguminosae	
138	Acacia (Acacia spp)	SC
139	Alfalfa (Medicago sativa)	SI
140	Bean (Phaseolus aureus)	SC
141	Bean (P. lunatus)	SC-S
142	Bean (P. multiflorus)	SC
143	Bean (P. vulgaris)	(SC-S)
144	Broadbean (Vicia faba)	SC
145	Cassia (Cassia spp)	SC
146	Clover (Trifolium hybridum)	SI
147	Clover (T. incarnatum)	SI
148	Clover (T. pratense)	SI
149	Clover (T. repens)	SI
150	Crotalaria (Crotalaria juncea)	SC
151	Honeylocust (Gleditsia triacanthos)	SC
152	Hyacinth-bean (Dolichos lablab)	SC
153	Ky.coffeetree (Gymnocladus dioica)	D
154	Lentil (Lens esculenta)	SC-S
155	Lespedeza (Lespedeza striata)	SC
156	Locust (Robinia pseudoacacia)	SC
157	Pea (Pisum sativum)	(SC-S)
158	Peanut (Arachis hypogaea)	(SC-S)
159	Pigeon-pea (Cajanus indicus)	SC
160	Soybean (Glycine soja)	(SC-S)
161	Sweetpea (Lathyrus odoratus)	(SC-S)
	Geraniaceae	
162	Geranium (Pelargonium graveolens)	SC
163	Geranium (P. odoratissimum)	SC
	Linaceae	
164	Flax (Linum usitatissimum)	SC-S
	Erythroxylaceae	
165	Coca (Erythroxylum coca)	SI[3]
	Zygophyllaceae	
166	Guaiacum (Guaiacum officinale)	SC
	Rutaceae	
167	Citrus (Citrus spp)	SC[2]
168	Torch-wood (Amyris elemifera)	SC
	Meliaceae	
169	Mahogany (Swietenia mahogani)	SC
	Euphorbiaceae	
170	Castor bean (Ricinus communis)	SC-M
	Buxaceae	
171	Boxwood (Buxus sempervirens)	SC-M
	Anacardiaceae	
172	Pistachio (Pistacia cabulica)	D
173	Pistachio (P. lentiscus)	D
174	Pistachio (P. vera)	D
	Aquifoliaceae	
175	Holly (Ilex spp)	D
	Aceraceae	
176	Maple (Acer spp)	SC
	Rhamnaceae	
177	Buckthorn (Rhamnus cathartica)	D
178	Buckthorn (R. frangula)	SC
179	Buckthorn (R. infectoria)	D
180	Buckthorn (R. purshiana)	SC
	Vitaceae	
181	Grape (Vitis vinifera)	SC
	Tiliaceae	
182	Basswood (Tilia spp)	SC

/1/ Self-compatible, fertile by means of its own pollen; self-incompatible, sterile to its own pollen; monoecious, staminate and pistillate flowers borne on same plant; dioecious, staminate and pistillate flowers born on separate plants; apomictic, reproduction without fertilization. /2/ Some plants apomictic. /3/ Heterostyled, i.e., stigma and stamens inserted at different levels.

109. BREEDING SYSTEMS: PLANTS (Concluded)

Systems listed below indicate the usual classification of breeding. Where variability exists within a species, the predominating system is enclosed in parentheses.

SC-S = species predominately self-compatible, no imbreeding degeneration; SC = self-compatible, intermediate, with perhaps a predominance of outcrossing; SC-M = self-compatible, monoecious, therefore rarely selfed under open pollination; SI = self-incompatible; D = dioecious; A=apomictic.

	Species	System[1]
	Dicotyledones (continued)	
	Malvaceae	
183	Cotton (Gossypium spp)	SC-S
184	Hibiscus (Hibiscus cannabinus)	SC
	Bombacaceae	
185	Baobab (Adansonia digitata)	SC
186	Durian (Durio zibethinus)	SC
187	Silk-cotton tree (Bombax ceiba)	SI
188	Silk-cotton tree (Ceiba casearin)	SC
	Sterculiaceae	
189	Cacao (Theobroma cacao)	SI
190	Sterculia (Sterculia urens)	SC
	Dilleniaceae	
191	Actinidia (Actinidia chinensis)	D
	Theaceae	
192	Camellia (Camellia sasanqua)	SC
193	Tea (Thea sinensis)	SC
	Guttiferae	
194	Mangosteen (Garcinia mangostana)	A
	Bixaceae	
195	Annatto-tree (Bixa orellana)	SC
196	Cochlospermum (Cochlospermum gossypium)	SC
	Violaceae	
197	Violet (Viola odorata)	SC
	Passifloraceae	
198	Passion-flower (Passiflora edulis)	SC
199	Passion-flower (P. ligularis)	SI
200	Passion-flower (P. quadrangularis)	SI
	Cariceaceae	
201	Papaya (Carica papaya)	D
	Punicaceae	
202	Pomegranate (Punica granatum)	SC
	Lecythidaceae	
203	Brazil-nut (Bertholletia excelsa)	SC
204	Lecythis (Lecythis sabucajo)	SC
	Myrtaceae	
205	Eucalyptus spp	SC

	Species	System[1]
	Dicotyledones (continued)	
	Myrtaceae (concluded)	
206	Guava (Psidium guajava)	SC
207	Pimenta (Pimenta officinalis)	SC
208	Rose-apple (Eugenia jambos)	SI
	Umbelliferae	
209	Angelica (Angelica archangelica)	SC
210	Caraway (Carum carvi)	SC
211	Carrot (Daucus carota)	SC
212	Celery (Apium graveolens)	SC
213	Parsley (Petroselinum hortense)	SC
214	Parsnip (Pastinaca sativa)	SC
	Ericaceae	
215	Vaccinium (Vaccinium spp)	SC
	Sapotaceae	
216	Mimusops (Mimusops balata)	SC
217	Sapodilla (Achras zapota)	SC
	Ebenaceae	
218	Persimmon (Diospyros ebenum)	D
219	Persimmon (D. kaki)	D
220	Persimmon (D. virginiana)	D
	Oleaceae	
221	Ash (Fraxinus spp)	SC
222	Olive (Olea europaea)	SC
	Loganiaceae	
223	Strychnos (Strychnos nux-vomica)	SC
	Gentianaceae	
224	Gentian (Gentiana lutea)	SC
	Apocynaceae	
225	Funtumia (Funtumia elastica)	SC
226	Strophanthus (Strophanthus spp)	SC
	Convolvulaceae	
227	Sweetpotato (Ipomoea batatas)	SI
	Boraginaceae	
228	Borage (Borago officinalis)	SI
	Verbenaceae	
229	Teak (Tectona grandis)	SC

	Species	System[1]
	Dicotyledones (concluded)	
	Labiatae	
230	Catnip (Nepeta cataria)	SC
231	Lavender (Lavandula officinalis)	SC
232	Marjoram (Origanum majoram)	SC
233	Mint (Mentha spp)	SC
234	Sage (Salvia officinalis)	SC
235	Thyme (Thymus vulgaris)	SC
	Solanaceae	
236	Belladonna (Atropa belladonna)	SC
237	Eggplant (Solanum melongena)	SC
238	Pepper (Capsicum frutescens)	SC
239	Potato (Solanum tuberosum)	SC
240	Thorn-apple (Datura stramonium)	SC
241	Tobacco (Nicotiana rustica)	SC
242	Tobacco (N. tabacum)	SC
243	Tomato (Lycopersicon esculentum)	SC
	Scrophulariaceae	
244	Foxglove (Digitalis purpurea)	SC
	Bignoniaceae	
245	Catalpa (Catalpa speciosa)	SC
	Rubiaceae	
246	Cinchona (Cinchona spp)	SI
247	Coffee (Coffea liberica)	SI
	Valerianaceae	
248	Valeriana (Valeriana officinalis)	SC
	Cucurbitaceae	
249	Cultivated spp	SC-M
	Compositae	
250	Artichoke (Helianthus tuberosus)	SI
251	Chicory (Cichorium intybus)	SI
252	Dahlia (Dahlia pinnata)	SI
253	Dandelion (Taraxacum, some spp)	A
254	Dandelion (T. kok-saghyz)	SC
255	Endive (Cichorium endivia)	SC
256	Guayule (Parthenium argentatum)	SI[2]
257	Sunflower (Helianthus annuus)	SI

/1/ Self-compatible, fertile by means of its own pollen; self-incompatible, sterile to its own pollen; monoecious, staminate and pistillate flowers borne on same plant; dioecious, staminate and pistillate flowers born on separate plants; apomictic, reproduction without fertilization. /2/ Some plants apomictic.

110. EJECTION OF SPORES: FUNGI

Part I: SPORE DISPERSAL; DISTANCE EJECTED

	Species	Distance Ejected	
		Horizontal mm	Vertical mm
1	Aleuria vesiculosa	10-25	10-20
2	Ascobolus immersus	300	350
3	Auricularia mesenterica	0.4-0.5	
4	Basidibolus ranarum	10-20	
5	Coleosporium campanulae, C. petasidis a	0.6-0.9	0.3
6	Conidibolus villosus	40	
7	Coprinus atramentarius	0.05	
8	C. curtus, C. niveus	0.1-0.2	
9	Cyathus pallidus		900-1200
10	Dacryomyces delinquescens	0.5-0.7	
11	Empusa muscae	20-30	
12	Endophyllum euphorbiae-sylvaticae[1]	0.4-0.5	
13	Endothia parasitica	90	22
14	Exidia alba	0.4	
15	Geoglossum hirsutum	5	
16	Gymnosporangium juniperi-virginianae[1]		0.3-0.4
17	Hymenyces lactifluorum		10
18	Pilobolus klenii	2450	1860
19	P. longipes	2630	1860
20	Podospora curvicolla		>260-450
21	Puccinia spp, basidiospores[2]	0.6	0.3
22	P. graminis, aeciospores		7-8
23	P. pulverulenta, aeciospores		4-5
24	Sclerospora philippinenais, S. spontanea	1-2	
25	Sordaria fimicola		60-150
26	Sphaerobolus iowensis	5050	4000
27	S. stellatus	5660	4500
28	Tilletia tritici	1.4	0.5-1
29	Urmula geaster		20-30
30	Uromyces pose, aeciospores		9
31	U. pisi, aeciospores	15-20	15-20

/1/ Data applicable to basidiospores. /2/ Species include: P. annularis, P. arenariae, P. glechomatis, P. malvacearum.

Part II: SPORE DISPERSAL; SPECIAL FEATURES

	Species	Projectile Size	Initial Velocity m/sec	Mechanism Analogue	Spore-fall Period	Principal Mechanism of Dispersal
1	Ascobolus immersus	35-45μ x 55-65μ	10	Squirt-gun	Diurnal	Osmotic pressure in epiplasm of ascus plus elastic contractility of ascus wall.
2	Coprinus atramentarius	5.5μ x 10μ	0.04	Ballon-gun	Continuous	Excretion of small drop of water at spore hilum.
3	Pilobolus longipes	0.5 mm (dia)	14	Squirt-gun	Diurnal	Osmotic pressure in subsporangial swelling, plus elastic contractility of sporangium wall.
4	Sphaerobolus stellatus	1-1.3 mm (dia)	9	Sling-shot	Diurnal	Eversion of peridial layer by increase in osmotic pressure.

	Species	Special Feature of Projectile	Accessory Features in Dispersal	Tropistic Responses
1	Ascobolus immersus	Gelatinous envelope covers 8-ascospore cluster.	Asci protrude from paraphyses which hold bases of asci in position.	Positive heliotropism of apothecium and asci.
2	Coprinus atramentarius	Spores describe a curved trajectory in falling, known as a "sporabola."	Cystidia hold gills apart; autodigestion clears cystidia and gills before spore-fall.	Negative geotropism of stipe.
3	Pilobolus longipes	Non-wettable sporangial wall basally ringed with wettable gelatin.	Ocellus-like subsporangial swelling; light orients sporangiophore.	Positive heliotropism of sporangiophore and subsporangial swelling.
4	Sphaerobolus stellatus	Gleba mass adhesive because of high fat content.	Air spaces between tooth-sinuses prevent formation of vacuum.	Positive heliotropism of fruit-body.

/1/ For 24-48 hr.

III. PROPAGATION: CULTIVATED PLANTS

Methods listed, accompanied by preferred calendar periods, represent those widely used for the genera, but are not intended to indicate that all species of the genera can be propagated satisfactorily by each method. Horticultural varieties are not propagated by seeds, as the new plants (from seed) may very considerably from the parent plants.

	Species	Method[1]	Time
	Fruit and Nut Crops		
1	Almond (Prunus communis)	Shield bud	Summer
2	Apple (Pyrus malus	Whip graft	Winter
		Shield bud	Spring-summer
3	Avocado (Persea americana)	Patch bud	Spring
		Whip graft	Winter
4	Blackberry (Rubus spp)	Shoot	Spring
		Root cutting	Late winter
5	Blueberry (Vaccinium corymbosum)	Hardwood cutting	Early spring
		Softwood cutting	Early summer
6	Cherry (Prunus spp)	Shield bud	Summer
7	Citrus crops (Citrus spp)	Inverted-T bud	Spring-summer
8	Cranberry (Vaccinium macrocarpum)	Hardwood cutting	Fall
9	Dewberry (Rubus spp)	Tip layering	Summer-fall
10	Fig (Ficus carica)	Hardwood cutting	Winter-spring
		Simple layering	Winter
11	Grape (Vitis spp)	Hardwood cutting	Winter
		Whip graft	Late winter
		Chip bud	Spring
12	Hickory (Carya spp)	Veneer graft	Winter-spring
13	Peach (Prunus persica)	Shield bud	June-summer
14	Pear (Pyrus communis)	Whip graft	Winter
		Shield bud	Summer
15	Pecan (Carya illinoensis)	Patch bud	Spring
16	Plum (Prunus spp)	Top graft	Winter
		Shield bud	Spring-summer
17	Raspberry (Rubus occidentalis)	Tip layering	Late summer
18	Raspberry (R. strigosus)	Shoots	Fall-spring
		Root cutting	Fall
19	Strawberry (Fragaria spp)	Runners	Summer-fall
20	Walnut (Juglans spp)	Veneer graft	Late winter
		Patch bud	Spring-summer
	Herbaceous Perennials		
21	Begonia (Begonia spp)	Softwood cutting	Year-round
		Leaf cutting	Year-round
22	Caladium (Caladium spp)	Tuber division	Spring
23	Carnation (Dianthus caryophyllus)	Softwood cutting	Spring-summer
24	Chrysanthemum (Chrysanthemum spp)	Softwood cutting	Year-round
		Division	Fall
25	Coleus (Coleus blumei)	Softwood cutting	Year-round
26	Dahlia (Dahlia spp)	Softwood cutting	Spring
		Leaf-bed cutting	Spring
		Root division	Spring
27	Gladiolus (Gladiolus hortulanus)	Cormels	Fall
		Corm division	Spring
28	Hyacinth (Hyacinthus orientalis)	Scooping bulb	Summer
		Notching bulb	Summer
29	Iris (Iris germanica)	Rhizome division	Fall
30	Peony (Paeonia spp)	Division	Fall
	Trees and Shrubs: Broadleaf		
31	Abelia (Abelia grandiflora)	Softwood cutting	Summer
		Hardwood cutting	Fall
		Simple layering	Spring-summer
		Mound layering	Spring
32	Alder (Alnus spp)	Seed	Fall
		Hardwood cutting	Winter
		Whip graft	Winter
33	Barberry (Berberis spp)	Seed	Fall or spring
		Semi-hardwood cutting	Summer
		Hardwood cutting	Fall-winter
34	Basswood (Tilia spp)	Seed	Fall or spring
		Whip graft	Early spring
		Simple layering	Spring
		Air layering	Early spring
35	Birch (Betula spp)	Seed	Fall
		Cleft graft	Early spring
		Air layering	Spring
36	Boxwood (Buxus spp)	Semi-hardwood cutting	Summer
		Hardwood cutting	Fall-winter
		Simple layering	Spring-summer
37	Camellia (Camellia spp)	Semi-hardwood cutting	Spring-summer
		Air layering	Spring
38	Cotoneaster (Cotoneaster spp)	Seed	Fall or spring
		Semi-hardwood cutting	Summer
		Root graft	Early winter
39	Dogwood (Cornus spp)	Seed	Fall or spring
		Semi-hardwood cutting	Early summer
		Hardwood cutting	Summer
		Simple layering	Spring
		Air layering	Spring

	Species	Method[1]	Time
	Trees and Shrubs: Broadleaf (concluded)		
40	Elaeagnus (Elaeagnus spp)	Seed	Fall or spring
		Semi-hardwood cutting	Late summer
		Hardwood cutting	Fall-winter
		Simple layering	Spring-summer
		Mound layering	Spring
41	Hawthorn (Crataegus spp)	Seed	Fall or winter
		Whip graft	Spring
		Shield bud	Summer
		Simple layering	Spring
		Air layering	Spring
42	Holly (Ilex spp)	Semi-hardwood cutting	Summer
		Side graft	Spring
		Shield bud	Spring
		Simple layering	Spring-summer
		Air-layering	Spring
43	Lilac (Syringa spp)	Softwood cutting	Early summer
		Wedge graft	Winter
		Simple layering	Early spring
		Air layering	Early spring
44	Magnolia (Magnolia spp)	Seed	Fall
		Softwood cutting	Late spring
		Semi-hardwood cutting	Fall
		Side graft	Summer
		Air layering	Spring
45	Maple (Acer spp)	Seed	Fall
		Hardwood cutting	Winter
		Side graft	Winter
		Air layering	Spring
		Shield bud	Summer
46	Mockorange (Philadelphus spp)	Softwood cutting	Late spring
		Hardwood cutting	Winter
47	Oak (Quercus spp)	Seed	Fall or spring
		Side graft	Early spring
48	Poplar (Populus spp)	Seed[2]	
		Hardwood cutting	Fall
		Root graft	Early winter
		Air layering	Early spring
49	Privet (Ligustrum spp)	Softwood cutting	Late spring
		Hardwood cutting	Late summer
		Simple layering	Spring-summer
50	Rhododendron (Rhododendron spp)	Seed	Spring
		Semi-hardwood cutting	Mid-summer
		Saddle graft	Winter
		Veneer graft	Winter
		Simple layering	Spring
		Air layering	Spring
51	Rose (Rosa spp)	Semi-hardwood cutting	Late spring
		Splice graft	Spring
		Shield bud	Spring-summer
		Air layering	Spring-summer
52	Viburnum (Viburnum spp)	Seed	Spring
		Softwood cutting	Late spring
		Semi-hardwood cutting	Summer
		Side graft	Summer
		Simple layering	Spring-summer
	Trees and Shrubs: Conifers		
53	Arborvitae (Thuja spp)	Seed	Fall or spring
		Semi-hardwood cutting	Summer
		Hardwood cutting	Fall-winter
		Side or veneer graft	Fall-winter
54	Cypress (Cupressus spp)	Seed	Fall or spring
		Semi-hardwood cutting	Summer
		Veneer graft	Summer
55	Douglas fir (Pseudotsuga spp)	Seed	Fall or spring
		Veneer graft	Summer
56	Fir (Abies spp)	Seed	Fall or spring
		Veneer graft	Winter
57	Hemlock (Tsuga spp)	Seed	Fall or spring
		Side or veneer graft	Spring
		Semi-hardwood cutting	Summer
		Air layering	Early spring
58	Juniper (Juniperus spp)	Seed	Fall or spring
		Side graft	Winter
		Hardwood cutting	Winter
59	Pine (Pinus spp)	Seed	Fall or spring
		Veneer graft	Winter-spring
		Air layering	Spring-fall
60	Spruce (Picea spp)	Seed	Fall or spring
		Semi-hardwood cutting	Summer
		Veneer graft	Fall-winter
61	Yew (Taxus spp)	Seed	Fall or spring
		Hardwood cutting	Fall-winter
		Air layering	Spring

/1/ Propagation by seed may involve pretreatment. Seeds of those species having no apparent rest period may be sown in spring, those having a definite rest period should be artificially stratified or sown in fall. /2/ To be sown as soon as mature.

	Species	Seed-Bearing Age[1] yr	Good-Crop Frequency yr	Weight of 1000 Seeds[2] g	Dormancy Type[3]	Germination			
						Duration, da		Sprouting, %[4]	
						Untreated	Pretreated	In Lab	In Field
	Broadleaf Trees								
1	Alder (Alnus rubra)	10-100	3-5	0.7(0.4-1.2)	Embryo?	60	30-40	27	14
2	Ash (Fraxinus americana)	20-175	3-5	45(25-82)	Embryo	>60	40-60	38	20
3	Ash (F. pennsylvanica)	20-	1-3	26(18-41)	Embryo	60->90	40-60	42	20
4	Aspen (Populus tremuloides)	20->70	4-5	0.1	None	7		59	50
5	Basswood (Tilia americana)	15->100	1-3	91(57-151)	Embryo + seed coat	200-1000	30-60	34	20
6	Beech (Fagus grandifolia)	40-100	2-3	284(197-349)	Embryo	150-160		85	40
7	Birch (Betula lenta)	40-	1-2	0.7(0.5-0.9)	Embryo?	90	30	43	15
8	Birch (B. alleghaniensis)		1-2	1(0.5-1.6)	Embryo?	>120	30-40	27	15
9	Birch (B. papyrifera)	15->70	1-3	0.3(0.1-0.7)	Embryo?	>100	30-40	34	15
10	Butternut (Juglans cinerea)	20-80	2-3	15,120(11,340-30,240)	Embryo + seed coat?	>110	45-60	65	50
11	Catalpa (Catalpa speciosa)	20-	2-4	22(15-28)	None?	60		75	70
12	Cherry (Prunus serotina)	10-125	1-3	94(56-146)	Embryo + seed coat?	>190	30	63	30
13	Chestnut (Castanea dentata)	20->150	2-3	3489(2835-4536)	Embryo	100	30-45	72	55
14	Coffeetree (Gymnocladus dioica)	20->100	1-2	1649(1243-2160)	Seed coat	200	60->90	75	50
15	Cottonwood (Populus deltoides)	10-death	1-3	1(0.8-2.3)	None	2-6		88	80
16	Elm (Ulmus americana)	15-300	1-3	6.7(4.8-9.4)	Embryo (variable)	90	15-60	63	15
17	Elm (U. rubra)	15-200	2-4	11.1(8.4-13)	Embryo[5]	90->120	50-70	17	10
18	Hackberry (Celtis occidentalis)		1-3	105(84-130)	Embryo + seed coat?	60-100	60	41	20
19	Hickory (Carya glabra)	30-300	1-2	2268(2016-2592)	Embryo	250-300	30-45	85	40
20	Hickory (C. ovata)	40-300	1-3	4536(3024-5670)	Embryo	300-350	45-60	80	55
21	Hickory (C. tomentosa)	25->200	2-3	5040(4,014-13,341)	Embryo	300-350	45-60	66	65
22	Honeylocust (Gleditsia triacanthos)	10-100	1-2	162(112-259)	Seed coat	120-180	15-40	50	50
23	Locust (Robinia pseudoacacia)	6-60	1-2	19(13-28)	Seed coat	40-70	10-25	68	25
24	Maple (Acer rubrum)		1-3	12(12-36)	Embryo (variable)	>90	30-40	46	58
25	Maple (A. saccharinum)	35-	1-3	324(239-504)	None	20-30		76	18
26	Maple (A. saccharum)	to >200	3-7	169(50-142)	Embryo	>150	30	39	15
27	Oak (Quercus alba)	20-300	4-10	3024(2160-6480)	None	30-50		78	66
28	Oak (Q. coccinea)	20-150	Irregular	1620(1120-2926)	Embryo	>240	60	62	60
29	Oak (Q. falcata)	25-125	1-2	1762(578-1163)	Embryo	>240	30-40	>90	65
30	Oak (Q. rubra)	25-200	2-3	3240(1779-5670)	Embryo	>300	40-60	58	70
31	Oak (Q. velutina)	20-100	2-3	1814(1134-3629)	Embryo	>240	30-50	47	>50
32	Pecan (Carya illinoensis)	20-300	1-2	4536(2835-8247)	Embryo	200-300	45-60	50	50
33	Sweetgum (Liquidambar styraciflua)	20-150	1-3	6(5-7)	Embryo?	120-200	20-60	70	50
34	Sycamore (Platanus occidentalis)	25-250	1-2	2.2(2-3)	Embryo?	30-60	15-20	35	20
35	Tupelo (Nyssa aylvatica)			137(113-245)	Embryo	>150	30-60	30	20
36	Walnut (Juglans nigra)	12-	Irregular	11,340(4,536-22,680)	Embryo + seed coat	100-300	15-40	75	55
37	Yellow-poplar (Liriodendron tulipifera)	15->200	Irregular	32(19-45)	Embryo + seed coat?	90-180	50-70	5	3
	Conifers								
38	Alaska-cedar (Chamaecyparis nootkatensis)	15-300	Occasional	4.2(2.5-6.9)	Embryo?	>300	60	10	5
39	Baldcypress (Taxodium distichum)		3-5	95(50-349)	Embryo, + seed coat?	60-110	30-50	12	8
40	Cypress (Cupressus arizonica)		1-3	11.3(6.7-16.8)	Embryo?	75	30	26	15
41	Douglas-fir (Pseudotsuga menziesii)	15-600	3-5	10.8(6.7-22.7)	Embryo + seed coat?[6]	60->90	15->30	85	55
42	Fir (Abies amabilis)	30-300	2-3	40(30-55)	Embryo (variable)	100	30	22	15
43	Fir (A. balsamea)	20->60	2-4	7.6(4.8-15.1)	Embryo (variable)	210	60-120	22	15
44	Fir (A. concolor)	40-200	3-5	30(17-55)	Embryo (variable)	>100	30	34	15
45	Fir (A. grandis)	20-300	2-3	20(10-36)	Embryo? (variable)	100	30	28	15
46	Fir (A. magnifica)	50->200	2-3	69(41-113)	Embryo (variable)	>100	30-45	25	15
47	Fir (A. procera)	30-300	Infrequent	31(24-49)	Embryo (variable)	100	30	24	15
48	Hemlock (Tsuga canadensis)	30->400	2-3	2.4(1.3-3.4)	Embryo (variable)	200	60	38	20
49	Hemlock (T. heterophylla)	25-300	2-5	1.5(0.9-2.1)	Embryo (variable)	>90	30	56	30
50	Incense-cedar (Libocedrus decurrens)	20->200	3	30(16-71)	Embryo? (variable)	>60	20-30	50	25
51	Juniper (Juniperus scopulorum)	10-300	2-5	11(11-25)	Embryo + seed coat	>200	20-30	22	20
52	Larch (Larix occidentalis)	40->60	5-6	3.2(2.3-4.6)	Embryo? (variable)	60	20-30	27	20
53	Pine (Pinus banksiana)	5->80	3-4	3.4(1.8-6.4)	Embryo (occasional)	15-60		68	45
54	Pine (P. echinata)	16->280	3-10	9.4(7.3-12.4)	Embryo?	60-120	15-45	68	35
55	Pine (P. elliottii)	12->150	1-10	31(28-35)	Embryo? (occasional)	45	20-40	61	30
56	Pine (P. jeffreyi)	8->150	2-6	113(84-146)	Embryo (occasional)	60-90		68	50
57	Pine (P. lambertiana)	40-300	3-5	216(142-302)	Embryo? (variable)	120	40	56	35
58	Pine (P. monticola)	15-300	4-6	17(14-32)	Embryo? + seed coat?	200	60-90	48	30
59	Pine (P. palustris)	20->150	3-7	108(76-119)	Embryo? (rare)	30-40	35	54	35
60	Pine (P. ponderosa)	20-300	2-5	38(20-66)	Embryo? (occasional)	60	30	59	45
61	Pine (P. resinosa)	25->200	3-7	8.7(6.4-15.1)	None	30		75	55
62	Pine (P. strobus)	15-250	3-5	16.8(8.6-22.7)	Embryo	60-100	30-40	64	50
63	Pine (P. taeda)	12->60	3-10	25(18-28)	Embryo?	70	35-45	60	30
64	Pört-Orford-cedar (Chamaecyparis lawsoniana)	8-200	4-5	2.2(0.8-5.7)	Embryo?	60-110	60	52	25
65	Redcedar (Juniperus virginiana)	10-175	2-3	10(8-26)	Embryo + seed coat	>180	20-30	42	30
66	Redcedar (Thuja plicata)	16->200	2-5	1.1(0.9-2.2)	Embryo (variable)	40	20	51	35
67	Redwood (Sequoia sempervirens)	20->300	1-3	3.7(1.5-7.7)	Embryo? (variable)	40-60		10	5
68	Sequoia (S. gigantea)	125->300	1-3	5(4.5-8.4)	Embryo? (variable)	40-60		25	15
69	Spruce (Picea engelmannii)	16->200	2-3	3.4(2.3-6.6)	Embryo (occasional)	50		69	45
70	Spruce (P. glauca)	30-	2-6	1.9(1.1-3.2)	Embryo	50-140	30-45	50	35
71	Spruce (P. mariana)	30-250	4-5	3(1.9-5.1)	Embryo	30-80	20-30	64	40
72	Spruce (P. rubens)	30-	3-8	3.2(1.6-4.5)	Embryo	30-50	20-30	60	40
73	Spruce (P. sitchensis)	25-300	3-4	2.2(1.1-2.9)	Embryo (variable)	60	50	60	40
74	White-cedar (Chamaecyparis thyoides)	4->100	1-3	1.0(0.9-1.1)	Embryo?	60-110	60	84	40
75	White-cedar (Thuja occidentalis)	30->100	5	1.3(0.8-2.5)	Embryo (variable)	50	30	46	30

/1/ Age of most abundant production. /2/ Cleaned. /3/ Dormancy may be general, variable (dormant and non-dormant seeds in same sample), occasional, or rare. Type is general unless otherwise indicated. /4/ Great variation reported. /5/ Northern sources only. /6/ Variable.

113. PHENOLOGICAL VALUES: FOREST TREES, U. S. A.

Within a species there is variation in time of growth expressions, depending upon such factors as latitude, altitude, slope, distribution of rainfall, and earliness or lateness of growing season. Many species have a broad distribution. Growth-period values are averages. Dates of stages where the growing season is short are enclosed in parentheses; dates of stages not so enclosed are for the long growing season. When the month is followed by I., growth stage occurs during first 10 days of the month; by II. during second 10 days; by III. during last 10 days. When no number appears after the month, growth stage occurs during the entire month. Species indicated by an asterisk (*) are evergreen; all other species are deciduous.

	Species	Leafing	Leaf Falling	Flowering[1]	Seed Maturing	Seed Falling	Height Growth	Diameter Growth
				Eastern United States				
1	Ash, black (Fraxinus nigra)	May III-June III	Sept III- Oct I	May III	July II-Aug III	July III- Oct III[4]	May III-July II	May III-Sept I
2	Ash, green (F. pennsylvanica)	Apr (Apr III- June I)	(Sept II- Oct I)	Apr II- Apr III (Apr III- May I)			(Apr III-July II)	(Apr II- July III)
4	Ash, white (F. americana)	Apr II- Apr III (May III- June I)	Oct I- Nov I (Sept III- Oct I)	Apr I- May I (May I- May II)	(To Aug III)	(Sept I- Oct III)	(May III- June III)	(May II- July III)
5	Aspen, bigtooth	Apr II- May I	Oct I- Oct II	Apr I- Apr II	Apr III	May I- May II		
7	(Populus grandidentata)	(May III- June II)	(Oct I- Oct II)	(Apr III- May I)	(May II)	(May III- June I)		
8	Baldcypress (Taxodium distichum)	Mar II- Apr II	Oct III- Nov III	Mar I- Apr II	Oct 1 - Oct II	Oct III- Dec III[2]		
9	Basswood, American	Apr III- May I	Oct I- Nov I	June	Aug	Sept I- Oct II+	Apr III- June II	June II- Sept II
10	(Tilia americana)	(May III-)	(Sept III- Oct I)	(July III)	(Aug III)	(Sept)		
11	Beech, American	Mar	Nov 1- Dec II	Apr I- Apr II	To Sept II	Sept III- Nov I		
12	(Fagus grandifolia)	(May- June II)	(Oct)	(June)	(To Sept I)	(Oct II-)		(Apr II- July I)
13	Birch, gray (Betula populifolia)	Apr III- May II	Oct	Apr III- May II	Sept III	Oct I- Nov III+		May III- Aug I
14	Birch, paper	Apr III- May I	Oct	Apr III- May I	To July III	Aug I -		
15	(B. papyrifera)	(May III- June I)	(Sept III- Oct III)	(June I)	(Sept II- Sept III)	(Oct)		
16	Birch, sweet (B. lenta)	Apr II- May III	Oct	Apr I- May I	Aug III- Sept I	Sept II- Oct III+		
17	Birch, yellow	Apr III- May I	Oct II- Oct III	May III	Aug I	Apr III		Aug II- Oct III+
18	(B. alleghaniensis)	(May II- June I)	(Sept III- Oct III)	(May II)	(Aug II)	(Sept III-)	(May III- Aug I)	(June II- Aug I)
19	Buckeye, Ohio (Aesculus glabra)	Mar III- May I	Oct	Mar III- May II	To Sept II	Sept III- Oct II		
20	Butternut (Juglans cinerea)	Apr II- May II	Sept II- Oct II	Apr II- May II	Sept III	Oct I- Nov II		
21	Cherry, black	Mar III- Apr II	Oct II- Nov I	Apr	To June III	July I- Aug III+	Mar II- June III	May III- Sept III
22	(Prunus serotina)	(May II- June I)	(Sept III- Oct I)	(June I)	(Aug II)	(Sept I-)		
23	Chestnut (Castanea dentata)	Apr III- May II	Oct II- Nov III	June III- July I	Sept III- Oct I	Oct II- Nov III		
24	Cottonwood, eastern	Mar II- Apr I	Oct II- Nov I	Mar I- Mar II	Apr I	Apr II- Apr III		
25	(Populus deltoides)	(May I- May II)	(Sept II- Oct II)	(Apr III- May I)	(May II- May III)	(May III- June III)		
26	Dogwood, flowering	Mar III- Apr II	Oct I- Nov I	Mar II- Apr II	To Oct III	Nov		Apr II- July I
27	(Cornus florida)	(May I- May II)	(Oct I- Oct II)	(May I- May II)	(Sept III)	(Oct II- Nov III)		
28	Elm, American	Mar III- Apr I	Oct I- Nov I	Feb I- Mar I	Mar II- Mar III	Apr		
29	(Ulmus americana)	(May III- June I)	(Oct I- Oct II)	(May II- May III)	(June I)	(July III-)		(May II- Aug I)
30	Elm, rock (U. thomasii)	Apr II- May I	Sept III- Oct II	Apr	May II	May III- July I		
31	Elm slippery	Mar III- Apr I	Oct	Feb III- Mar I	Apr I	Apr II- Apr III		
32	(U. rubra)	(Apr III- May I)	(Sept III- Oct II)	(Apr II- Apr III)	(May II)	(May III- June I)		(Apr III- Aug III)
33	Elm, winged (U. alata)	Mar III- Apr II		Feb I- Mar I	Apr I- Apr II	Apr III-		Apr III- July II
34	Fir, balsam (Abies balsamea)*	May III- June I	Sept III- Oct II	May II- May III	Aug III- Sept I	Sept II- Nov III	May III- Aug II	May III- Sept I
35	Hemlock, eastern (Tsuga canadensis)*	May III- June II	Sept II- Oct III	May II- June I	Sept I- Oct II	Oct III- Apr III[2]	May III- Aug II	
36	Hickory, mockernut (Carya tomentosa)	Apr	Oct	Apr II- May I	To Sept III	Oct+		Apr I- July II
37	Hickory, pignut	Apr	Oct I- Nov I	Apr II- May I	To Oct I	Oct I- Nov I+		
38	(C. glabra)	(May I- May II)	Oct	(May II- May III)	(To Sept III)			
39	Hickory, shagbark (C. ovata)	Apr I- May I	Oct	Apr II- May III	Sept II-Sept III	Oct I- Nov I+		
40	Holly, American (Ilex opaca)*	Apr I- May I	Mar	Apr II- June I	Sept II- Oct II	Mar		
41	Locust, black (Robinia pseudoacacia)	Apr I- May I	Sept III- Oct III	Apr III- May III	Sept II- Oct I	Oct II- Dec III[2]		
42	Maple, red	Mar I- Apr II	Oct III- Nov I	Jan II- Jan III	To Mar II	Mar III- Apr II		May I- July II
43	(Acer rubrum)	(May II- June I)	(Sept III- Oct I)	(May)	(To June III)	(July I)	(May I- July III)	
44	Maple, silver	Feb III- May II	Oct III- Nov I	Feb I- Mar I	To Mar III	Apr		
45	(A. saccharinum)	(Apr II- May I)	(Oct II- Oct III)	(Mar III- Apr II)	(May I- May II)	(May I- June I)	(Apr II- July III)	(Apr III- Aug II)
46	Maple, sugar	Apr II- May I	Oct I- Nov I	Apr III- May I	to Sept II	Sept III- Oct III+	Apr II- May III	June II- Aug III
47	(A. saccharum)	(May III- June I)	(Sept III- Oct I)	(May II- May III)	(Aug I)	(Sept I-)	(May II- Aug III)	(June I- Sept I)
48	Mulberry, red (Morus rubra)	Apr	Oct	Apr II- May II	June	July I- Aug III		
49	Oak, black (Quercus velutina)	Apr III- May III	Oct III- Nov III	Apr III- May II	Sept	Oct I- Nov I		
50	Oak, bur	Apr	Oct III- Nov II	Apr- III- May I				
51	(Q. macrocarpa)	(May II- May III)	(Sept III- Oct II)	(June I- June II)	(Sept II- Sept III)	(Oct)		
52	Oak, northern red	Apr II- May I	Oct III- Nov I	Apr III- May I	Sept I- Sept II	Sept III- Nov I		Apr II- July III
53	(Q. rubra)	(May III- June I)	(Oct I- Oct II)	(May III- June I)	(Sept I)	(Sept II)	(May III- June III)	
54	Oak, post	Apr	Oct II- Nov I	Apr II	Sept III- Oct I	Oct II- Nov I		Apr I- July I
55	(Q. stellata)	(May I- May II)	(Oct II-)	(May II)		(Oct I)		
56	Oak, scarlet (Q. coccinea)	Apr III- May II	Oct II-	Apr III- May I	Sept	Oct		
57	Oak, southern red (Q. falcata)	Apr		Apr I- May I	Sept	Oct		Apr I- July I
58	Oak, white	Mar III- Apr II	Oct III- May I	Apr I- Apr II	Sept III- Oct I	Oct II- Nov I		Mar III- July III
59	(Q. alba)	(May II- June I)	(Oct II- Oct III)	(May II)	(Sept II- Sept III)	(Sept III-)		
60	Pine, eastern white	May I- Aug I	Sept I- Oct II	May II- June I	Aug I- Sept III	Oct	Apr III- June III	Apr III- Sept III
61	(Pinus strobus)*	(May III- Aug II)	(Sept II- Sept III)	(June III)	(Sept I- Sept II)	(Sept II- Oct III)	(May II- Aug I)	(May I- Sept III)
62	Pine, jack (P. banksiana)*	May III-	Oct II-	May II- June I	Sept I- Sept II	Sept III-[3]	May I- July I	
63	Pine, loblolly	Feb II-		Feb III- Mar I	Oct	Nov I- Dec III[2]		
64	(P. taeda)*	(Mar III-)	(Oct II- Dec II)[4]	(Apr I- Apr II)	(Sept III- Oct I)	(Oct II- Dec III[2])	(Mar III- Aug I)	(Mar III- Aug II)

/1/ For conifers, dates of pollination are given. /2/ Seed fall continues through the winter, in smaller quantities. /3/ Seedfall continues for several years. /4/ Leaf fall continues throughout the year.

Within a species there is variation in time of growth expressions, depending upon such factors as latitude, altitude, slope, distribution of rainfall, and earliness or lateness of growing season. Many species have a broad distribution. Growth-period values are averages. Dates of stages where the growing season is short are enclosed in parentheses; dates of stages not so enclosed are for the long growing season. When the month is followed by I, growth stage occurs during first 10 days of the month; by II, during second 10 days; by III, during last 10 days. When no number appears after the month, growth stage occurs during the entire month. Species indicated by an asterisk (*) are evergreen; all other species are deciduous.

	Species	Leafing	Leaf Falling	Flowering[1]	Seed Maturing	Seed Falling	Height Growth	Diameter Growth
				Eastern United States (concluded)				
65	Pine, longleaf							
	(Pinus palustris)*	Mar I-	Sept I- Dec III[4]	Feb I-Mar III	Sept I-Oct II	Oct II-Nov III[4]		Mar I-Aug III
66	Pine, pitch (P. rigida)*	May III-July III		Apr III-May II	To Oct III	Nov I-Apr III	Apr III-July I	Apr III-
67	Pine, red (P. resinosa)*	May II-Aug III	Oct I-	June I-June II	Sept II-Sept III	Oct I- Dec II[2]	May I-Aug I	May I-Sept III
68	Pine, shortleaf	Feb III-	Sept I- Dec III[4]	Feb III-				
69	(P. echinata)*	(May III-July III)		(May II)	(Oct I- Oct II)	(Oct III- Dec III[2])	(May I-July III)	(Mar III-Aug III)
70	Pine, slash (P. elliottii)*	Feb III-		June III-Feb II	Sept I- Sept II	Sept III- Nov I		
71	Redcedar							
	(Juniperus virginiana)*	Mar II- May II	Oct	Mar II- May II	Sept III-Nov III	Feb I- Mar III		
72	Spruce, black							
	(Picea mariana)*	June I-		June I	Aug III-Sept II	Sept III-[5]	June I-Aug II	
73	Spruce, red (P. rubens)*			June I	To Sept I	Sept II-	June I-July III	May III-Sept I
74	Spruce, white (P. glauca)*	May II-May III		May	Aug III-Sept I	Sept II-Nov III	May II July III	
75	Sweetgum							
	(Liquidambar styraciflua)	Mar II- Apr III		Mar II- May I	Sept II-Sept III	Oct		May III-Aug II
76	Sycamore, American							
	(Platanus occidentalis)	Apr I- May I	Oct I-Nov I	Apr I- May I	Sept III	Oct I- Mar I[4]	Apr I-July II	
77	Tamarack (Larix laricina)	May	Sept III-Oct III	Apr III-May III	Aug III- Sept I	Sept II- Sept III	May III-Aug II	May III-July I
78	Tupelo, black	Apr		Apr II-May I	To Sept I	Sept II-Oct II		
79	(Myssa sylvatica)	(May)	(Sept III-Nov I)	(May III-June I)	(To Sept III)	(Sept III-Oct III)		
80	Walnut, black	Apr	Sept III-Oct III	Apr I- May I	Sept	Oct I-Nov I		
81	(Juglans nigra)	(May II-May III)	(Oct I-Oct II)	(May)	(Sept)			
82	White-cedar, northern							
	(Thuja occidentalis)*	May II-		May III	Aug III-Sept III	Oct	May II-Aug III	May III-Sept I
83	Willow, black	Mar III- Apr II	Oct II-Nov I	Mar II- Mar III	Apr I- Apr II	Apr III- May II		
84	(Salix nigra)	(Apr III- May II)	(Oct)	(Apr III-May I)	(May II- May III)	(June)		
85	Yellow-poplar	Mar III-Apr II	Oct II-Nov I	Apr II	Sept II-Sept III	Oct I-Jan I		
86	(Liriodendron tulipifera)	(Apr III-May II)	(Sept I-Oct III)	(May I- June I)			(Apr II-July III)	(May I-Aug I)
				Western United States				
87	Alder, red	Mar III-Apr II	To Nov I	Mar II-Apr I	Sept I			
88	(Alnus rubra)	(Apr II- May I)	(To Oct II)	(Apr III-May I)	(Oct II)	(Nov I-Dec III[2])		
89	Aspen, quaking	Apr III	Oct II-Nov II	Apr I- Apr II	May I	May II	Apr II-	
90	(Populus tremuloides)	Apr III	(Sept)	(June III)	Sept (June III)	(July I)	(May III- Aug I)	(May III-Aug III)
91	Cottonwood, black	Apr	To Nov I	Apr II- Apr III	May III			
92	(P. trichocarpa)	(Apr III- May II)	(Sept III- Oct I)	(May II-May III)	(June III)			
93	Dogwood, Pacific	Mar III- Apr II	To Nov I	Apr III-May II	Aug II			
94	(Cornus nuttallii)	(Apr III- May I)	(To Oct III)	(May I- June I)	(Sept I)			
95	Douglas fir	May I- May II	Oct II-Nov I	Apr II- Apr III	Aug III- Sept II	Sept II-Oct II	May I-July III	May I- Aug II
96	(Pseudotsuga menziesii)*	(June III)	(Sept II-Sept III)	(July I)	(Aug II)	(Aug III-Sept II)	(June I-July III)	(May III- Aug I)
97	Fir, alpine	June I	Aug II-Sept III	June I	Sept II	Sept III- Oct I	May III-July II	May III- Aug I
98	(Abies lasiocarpa)*	(June III)	(Sept I-Oct III)	(June III-July I)	(Aug III- Sept I)	(Sept II- Sept III)	(June II-July III)	
99	Fir, grand	May I-		May I		Sept II-Oct III		Apr III-Aug II
100	(A. grandis)*	(June I-)		(June III)	(Aug)	(Sept I-Oct III)		(May II-Sept II)
101	Fir, white	May II	Sept I-	June I			May I	
102	(A. concolor)*	(July I)	(Oct)	(May I- May II)		(Oct)	(June III- Aug I)	(May I- Aug I)
103	Hemlock, western	May I-		May I	Aug II-Sept I	Sept II -		
104	(Tsuga heterophylla)*	(June I)	(Sept I- Dec III)	(May II)	(Sept II- Sept III)	(Oct I- Dec III[2])	(May III- Aug I)	(May II-Sept I)
105	Incense-cedar							
	(Libocedrus decurrens)*	May III		May III	May III	Oct I-Nov III	May III-Aug III	Apr II- Aug III
106	Juniper, Rocky Mt.	May III		May III	Sept III	Oct I-	May I-	
107	(Juniperus scopulorum)*	(June I)		(June III)	(Oct I- Oct II)		(May III-)	
108	Larch, western	Apr II-		Apr III	Sept I	Oct I-		Apr III-July II
109	(Larix occidentalis)	(May II-)		(May I- June III)	(Aug I)	(Sept I-)		(May III-July II)
110	Maple, bigleaf	Mar I- Apr I	Oct III-Nov III	Mar II- Apr I	To Sept III	Oct I- Dec III[2]		May I-July III
111	(Acer macrophyllum)	(Apr II- May I)	(Sept III- Oct III)	(Apr III- May I)	(To Aug III)			
112	Oak, Calif. live							
	(Quercus agrifolia)*	Mar I- Apr III		Apr		Dec I- Dec III[2]		Mar III-July III
113	Oak, canyon live							
	(Q. chrysolepis)*	Apr III-June II		June I		Oct	Apr II-July II	Apr III-Aug III
114	Oak, Gambel	May III	Sept III- Oct I	May II- May III			May II	
115	(Q. gambelii)	(June I)	(Sept III)				(June I)	
116	Pine, Jeffrey							
	(Pinus jeffreyi)*	June II-June III	Oct II-Nov I	June II-June III		Sept II-Oct II	May II-Aug I	Apr II-Sept II
117	Pine, limber	May III-June II	Sept III- Oct III	June I	Sept	Oct	May III-July III	
118	(P. flexilis)*	(June I- June II)	(Oct)	(June III-July I)	(Aug III- Sept I)	(Sept II-Oct III)		
119	Pine, lodgepole	May	Oct I- Nov I	May II- May III	Sept I- Sept II	Sept III- Oct I[6]	May I-July II	
120	(P. contorta)*	(June III)	(Sept II- Oct III)	(July I- July III)	(Aug)	(Sept[6])	(June III-)	
121	Pine, ponderosa	May III- June I	Oct I- Nov I	May III- June I	Aug I- Sept III	Sept I- Nov III	May I-Aug I	Apr II-Sept II
122	(P. ponderosa)*	(June II- July III)	(Sept I- Oct I)	(June II- June III)	(Aug)	(Sept)	(June I-July II)	(May III- Aug III)
123	Pine, sugar							
	(P. lambertiana)*	July I-July II	Oct II-Nov II	June II-June III		Oct	May III-July II	Apr II- Aug III
124	Pine, western white	May II-		June III-July I		Sept III-	May II-	May I-July II
125	(P. monticola)*	(June -)		(June III-July I)	(Aug)	(Sept I-)		
126	Pinyon	May III- June I	Sept III- Oct III	May II- May III	Sept	Oct	May I-	
127	(P. edulis)*	(June II- Aug I)	(May III- June III)	(June II- June III)	(Aug I- Sept I)	(Sept III- Oct II)	(May III-July)	(June I-Sept I)
128	Redcedar, western		Sept II- Oct III	Apr III	Sept III	Sept III- Dec III[2]	May II-Sept I	Apr III- Oct I
129	(Thuja plicata)*			(May III)	(Aug II- Sept I)	(Sept II-)		(May II-Sept I)
130	Spruce, Engelmann	May III	Sept I-Sept II	May III- June I	Aug I- Sept I	Sept I- Oct I	May III-	May I-July II
131	(P. engelmannii)*	(June III)	(Sept I- Oct III)	(June III)	(Sept)	(Sept III- Oct II)	(June III-July III)	
132	Spruce, Sitka	Apr III-		May I		Sept III-		Apr III- Aug II
133	(P. sitchensis)*			(May III- June I	(Sept II- Sept III)	(Oct I- Dec III[2])	(May III-July II)	(May III- Sept I)

/1/ For conifers, dates of pollination are given. /2/ Seed fall continues through the winter, in smaller quantities. /4/ Leaf fall continues throughout the year. /5/ Cones are retained for 2-3 years during which seed fall continues. /6/ Most seeds are retained several years until cones are opened by a fire.

Values are approximate. Great variation exists within species.

Species	Height[1] ft	Crown Spread[2] ft	Trunk Diameter[3] ft	Relative Growth Rate
1 Alaska-cedar (Chamaecyparis nootkatensis)	60-90(130)	15-20	2-3(7)	Slow
2 Alder, red (Alnus rubra)	80-100(130)	20-40	1-3(5)	Rapid
3 Ash, black (Fraxinus nigra)	40-60(90)	20-30	1-2(5)	Slow
4 Ash, blue (F. quadrangulata)	40-50(120)	30-40	1-2(4)	Rapid
5 Ash, green (F. pennsylvanica)	35-50(85)	30-40	1-2(2.5)	Rapid
6 Ash, Oregon (F. latifolia)	60-80(130)	30-40	2-3(5)	Moderate
7 Ash, white (F. americana)	60-80(125)	50-70	2-3(6)	Rapid
8 Aspen, bigtooth (Populus grandidentata)	60-70(80)	20-30	1-2(3)	Rapid
9 Aspen, quaking (P. tremuloides)	40-60(120)	20-40	1-2(4.5)	Very rapid
10 Baldcypress (Taxodium distichum)	80-120(150)	20-30	2-5(12)	Slow
11 Basswood, American (Tilia americana)	60-80(125)	40-50	2-3(5)	Rapid
12 Basswood, white (T. heterophylla)	60-80(125)	40-50	1.5-2.5(3)	Moderate
13 Beech, American (Fagus grandifolia)	70-100(120)	60-80	1-3(4)	Slow
14 Birch, gray (Betula populifolia)	20-30(60)	15-25	0.6-1(1.5)	Rapid
15 Birch, paper (B. papyrifera)	50-70(120)	20-30	1-2(5)	Rapid
16 Birch, river (B. nigra)	70-80(100)	40-50	2-3(5)	Rapid
17 Birch, sweet (B. lenta)	50-60(80)	20-30	1-2(5)	Moderate
18 Birch, yellow (B. alleghaniensis)	60-80(100)	30-40	1-2(4)	Rapid
19 Boxelder (Acer negundo)	40-50(75)	30-40	1.5-3(6)	Very rapid
20 Buckeye, Ohio (Aesculus glabra)	30-60(90)	30-40	1-2(2.5)	Moderate
21 Buckeye, yellow (A. octandra)	70-90(100)	30-50	2-3(4)	Rapid
22 Buckthorn (Rhamnus purshiana)	30-40(60)	15-25	0.5-1(3)	Rapid
23 Butternut (Juglans cinerea)	40-60(110)	20-30	1-2(3)	Rapid
24 California-laurel (Umbellularia californica)	60-100(175)	30-50	1-3(6)	Moderate
25 Catalpa, northern (Catalpa speciosa)	30-60(120	40-50	1-3(5)	Rapid
26 Cherry, black (Prunus serotina)	50-60(100)	20-40	1.5-3(5)	Rapid
27 Chestnut, American (Castanea dentata)	70-90(120)	50-70	2-4(10)	Rapid
28 Chinkapin, golden (Castanopsis chrysophylla)	60-80(150)	40-60	1-2.5(8)	Rapid
29 Cottonwood, black (Populus trichocarpa)	80-120(225)	30-50	3-4(8)	Rapid
30 Cottonwood, eastern (P. deltoides)	80-100(175)	40-60	3-4(11)	Very rapid
31 Cottonwood, plains (P. sargentii)	50-80(110)	20-40	2-3(5)	Rapid
32 Cucumbertree (Magnolia acuminata)	70-90(100)	50-60	2-3(5)	Rapid
33 Cypress, Arizona (Cupressus arizonica	50-60(90)	15-25	1-2.5(5)	Slow
34 Dogwood, flowering (Cornus florida)	20-40(50)	25-35	0.5-1(1.5)	Slow
35 Dogwood, Pacific (C. nuttallii)	30-50(70)	20-30	0.5-1.5(2)	Slow
36 Douglas-fir (Pseudotsuga menziesii)	180-250(385)	15-40	4-6(15)	Rapid
37 Elm, American (Ulmus americana)	80-100(120)	80-110	2-4(11)	Rapid
38 Elm, rock (U. thomasii)	50-70(100)	20-30	1-2.5(5)	Rapid
39 Elm, slippery (Ulmus rubra)	50-70(90)	40-60	1-2(4)	Rapid
40 Fir, alpine (Abies lasiocarpa)	60-100(160)	15-25	1.5-2(3)	Moderate
41 Fir, balsam, (A. balsamea)	40-60(85)	20-25	1-1.5(3)	Rapid
42 Fir, California red (A. magnifica)	150-180(230)	20-40	4-5(10)	Moderate
43 Fir, Fraser (A. fraseri)	30-50(65)	20-25	1-2(2.5)	Moderate
44 Fir, grand (A. grandis)	120-160(250)	20-30	2-4(6)	Moderate
45 Fir, noble (A. procera)	140-200(260)	20-40	2.5-5(8)	Rapid
46 Fir, Pacific silver (A. amabilis)	140-160(250)	20-40	2-4(6)	Moderate
47 Fir, white (A. concolor)	120-150(200)	20-30	3-4(6)	Moderate
48 Hackberry (Celtis occidentalis)	40-80(130)	40-50	1-2(5)	Rapid
49 Hemlock, eastern (Tsuga canadensis)	60-80(160)	20-30	2-3(6)	Slow
50 Hemlock, mountain (T. mertensiana)	70-100(130)	20-30	2.5-3.5(5)	Moderate
51 Hemlock, western (T. heterophylla)	100-170(260)	15-25	2-5(9)	Moderate
52 Hickory, bitternut (Carya cordiformis)	50-60(170)	20-30	1-2(4)	Moderate
53 Hickory, mockernut (C. tomentosa)	50-70(100)	20-30	1-2.5(3.5)	Slow
54 Hickory, pignut (C. glabra)	50-60(85)	25-35	1-2(4)	Slow
55 Hickory, shagbark (C. ovata)	60-80(120)	20-30	1-2(4)	Slow
56 Hickory shellbark (C. laciniosa)	60-80(120)	20-30	1-2(4)	Slow
57 Holly, American (Ilex opaca)	40-50(100)	20-25	1-2(4)	Slow
58 Honeylocust (Gleditsia triacanthos)	70-80(140)	40-50	2-3(6)	Rapid
59 Hophornbeam, eastern (Ostrya virginiana)	30-40(55)	20-25	1-1.5(1.5)	Slow
60 Incense-cedar (Libocedrus decurrens)	80-110(190)	15-25	2.5-4(11)	Slow
61 Juniper, alligator (Juniperus deppeana)	30-50(60)	10-15	1.5-3(6)	Very slow
62 Juniper, Rocky Mt. (J. scopulorum)	20-40(55)	10-15	1-2(3)	Slow
63 Juniper, Utah (J. osteosperma)	15-20(30)	10-15	1-1.5(2.5)	Very slow
64 Juniper, western (J. occidentalis)	20-30(40)	10-20	1-2.5(3)	Slow
65 Larch, western (Larix occidentalis)	140-180(210)	20-40	3-4(8)	Slow
66 Locust, black (Robinia pseudoacacia)	40-60(100)	20-40	1-2(5)	Rapid
67 Madrone, Pacific (Arbutus menziesii)	40-80(125)	20-40	1-2(4)	Slow
68 Magnolia, southern (Magnolia grandiflora)	60-80(135)	30-35	2-3(4.5)	Moderate
69 Mahogany, West Indies (Swietenia mahagoni)[4]	30-40(60)	15-30	0.5-1(1.5)	Slow
70 Maple, bigleaf (Acer macrophyllum)	50-80(120)	30-60	1-3(8)	Rapid
71 Maple, red (A. rubrum)	50-70(120)	40-60	1-2.5(5)	Rapid
72 Maple, silver (A. saccharinum)	60-80(120)	40-50	2-3(7)	Rapid
73 Maple, sugar (A. saccharum)	60-80(135) 60-80(135)	40-50	2-3(5)	Slow
74 Mulberry, red (Morus rubra)	20-40(50)	20-30	0.5-1(1.5)	Moderate
75 Oak, black (Quercus velutina)	50-80(130)	40-50	2-3(7)	Moderate
76 Oak, blackjack (Q. marilandica)	20-30(55)	20-30	0.5-1.5(2)	Slow

/1/ Average range at maturity. Values for maximum height are enclosed in parentheses. /2/ Maximum crown spread of open-grown trees. Data primarily adapted and modified from Robinson, F. B., "Useful Trees and Shrubs." These values are not usually measured by foresters and may be more variable than the other data. They are presented here to show a general growth habit. /3/ Average range at maturity. Values for maximum diameter are enclosed in parentheses. Measurements at breast height (4.5 ft). /4/ Attains greater size in tropics.

114. SIZE AND GROWTH RATE: FOREST TREES, U. S. A. (Concluded)

Values are approximate. Great variation exists within species.

	Species	Height[1] ft	Crown Spread[2] ft	Trunk Diameter[3] ft	Relative Growth Rate
77	Oak, blue (Quercus douglasii)	50-80(130)	20-40	1-2(3)	Slow
78	Oak, bur (Q. macrocarpa)	70-80(170)	40-50	2-3(7)	Slow
79	Oak, California black (Q. kelloggii)	50-80(100)	30-50	1.5-2.5(11)	Slow
80	Oak, California live (Q. agrifolia)	30-60(110)	30-50	1-3(6)	Slow
81	Oak, California white (Q. lobata)	50-90(130)	40-60	305(10)	Rapid
82	Oak, canyon live (Q. chrysolepis)	60-80(100)	50-120	2-4(11)	Slow
83	Oak, chestnut (Q. prinus)	50-60(100)	30-40	2-3(6)	Moderate
84	Oak, chinkapin (Q. muehlenbergii)	60-80(160)	30-40	2-3(4)	Rapid
85	Oak, emory (Q. emoryi)	30-50(65)	20-40	1-2(3)	Slow
86	Oak, Gambel (Q. gambelii)	20-30(50)	20-30	0.5-1(1.5)	Slow
87	Oak, laurel (Q. laurifolia)	60-70(100)	20-40	2-3(7)	Moderate
88	Oak, live (Q. virginiana)	40-50(100)	40-75	3-4(11)	Moderate
89	Oak, northern red (Q. rubra)	60-70(150)	30-50	2-3(11)	Rapid
90	Oak, Nuttall (Q. nuttallii)	50-70(120)	20-40	1-2(3.5)	Moderate
91	Oak, Oregon, white (Q. garryana)	50-70(120)	50-80	2-3(8)	Slow
92	Oak, overcup (Q. lyrata)	40-70(110)	30-40	1.5-2.5(4.5)	Slow
93	Oak, pin (Q. palustris)	60-80(120)	40-50	2-3(5)	Rapid
94	Oak, post (Q. stellata)	40-50(100)	25-35	1-2(4)	Slow
95	Oak, scarlet (Q. coccinea)	70-80(110)	40-50	2-3(4)	Moderate
96	Oak, Shumard (Q. shumardii)	80-100(180)	40-60	4-5(8)	Rapid
97	Oak, southern red (Q. falcata)	60-80(110)	40-50	2-3(7)	Moderate
98	Oak, swamp chestnut (Q. michauxii)	60-80(120)	30-40	2-3(9)	Slow
99	Oak, swamp white (Q. bicolor)	60-70(100)	40-50	2-3(7)	Slow
100	Oak, water (Q. nigra)	60-70(125)	40-60	1.5-3(5)	Rapid
101	Oak, white (Q. alba)	80-100(150)	60-90	2.5-4(8)	Slow
102	Oak, willow (Q. phellos)	80-100(130)	30-50	1.5-3(6)	Moderate
103	Osage-orange (Maclura pomifera)	20-50(70)	30-40	1-2(5)	Moderate
104	Palmetto, cabbage (Sabal palmetto)	30-50(90)	10-20	1-1.5(2)	Slow
105	Pecan (Carya illinoenais)	90-120(180)	30-50	2-4(6)	Moderate
106	Persimmon (Diospyros virginiana)	30-50(130)	20-30	1-1.5(7)	Slow
107	Pine, Digger (Pinus sabiniana)	40-50(90)	15-25	1-2(4)	Moderate
108	Pine, eastern white (P. strobus)	80-120(220)	40-50	2-4(6)	Rapid
109	Pine, jack (P. banksiana)	30-60(90)	10-20	1-1.5(2)	Rapid
110	Pine, Jeffery (P. jefferyi)	90-100(130)	25-35	3-4(9)	Moderate
111	Pine, knobcone (P. attenuata)	60-80(100)	25-35	1-2(3)	Rapid
112	Pine, limber (P. flexilis)	30-50(85)	15-25	1.5-2.5(7)	Slow
113	Pine, loblolly (P. taeda)	90-110(190)	30-40	2-2.5(5)	Rapid
114	Pine, lodgepole (P. contorta)	30-70(150)	15-25	1-2.5(3)	Slow
115	Pine, longleaf (P. palustris)	80-120(150)	20-30	2-3(4)	Rapid
116	Pine, pitch (Pinus rigida)	50-60(100)	30-40	1-2(3)	Rapid
117	Pine, ponderosa (P. ponderosa)	100-180(235)	25-35	3-4(9)	Moderate
118	Pine, red (P. resinosa)	50-80(120)	20-40	2-3(5)	Rapid
119	Pine, shortleaf (P. echinata)	80-100(150)	25-35	2-2.5(4)	Rapid
120	Pine, slash (P. elliottii)	80-90(130)	30-40	1-2(3)	Rapid
121	Pine, spruce (P. glabra)	80-90(120)	20-30	2-2.5(4)	Rapid
122	Pine, sugar (P. lambertiana)	160-180(250)	20-40	2-4(10)	Rapid
123	Pine, Virginia (P. virginiana)	30-40(100)	15-25	1-1.5(3)	Moderate
124	Pine, western white (P. monticola)	150-180(210)	25-35	2.5-3.5(8)	Rapid
125	Pinyon (P. edulis)	15-30(50)	10-25	1-2(3)	Very slow
126	Pinyon, singleleaf (P. monophylla)	20-30(50)	10-25	1-2(3)	Very slow
127	Popular, balsam (Populus balsamifera)	60-80(100)	40-60	1-2(5)	Rapid
128	Port-Orford-cedar (Chamaecyparis lawsoniana)	140-180(225)	20-40	3.5-6(16)	Moderate
129	Redcedar, eastern (Juniperus virginiana)	40-50(100)	10-15	1-2(4)	Slow
130	Redcedar, western (Thuja plicata)	150-200(250)	20-30	4-8(20)	Rapid
131	Redwood (Sequoia sempervirens)	150-275(365)	30-40	6-12(20)	Rapid
132	Sassafras (Sassafras albidum)	40-70(110)	35-45	1-2.5(6)	Rapid
133	Sequoia, giant (Sequoia gigantea)	250-280(350)	30-60	10-15(38)	Rapid
134	Spruce, black (Picea mariana)	30-40(100)	20-30	0.5-1(3)	Slow
135	Spruce, blue (P. pungens)	70-100(150)	15-25	1-2(3)	Slow
136	Spruce, Engelmann (P. engelmannii)	100-120(165)	15-25	1-3(6)	Slow
137	Spruce, red (P. rubens)	60-70(120)	20-25	1-2(4)	Slow
138	Spruce, Sitka (P. sitchensis)	180-200(300)	25-35	2-5(16)	Rapid
139	Spruce, white (P. glauca)	60-70(120)	15-20	1.5-2(4)	Slow
140	Sugarberry (Celtis laevigata)	60-80(130)	30-40	1.5-2.5(5)	Moderate
141	Sweetgum (Liquidambar styraciflua)	80-140(200)	60-70	2-5(6)	Rapid
142	Sycamore (Platanus occidentalis)	80-120(175)	60-80	2-5(14)	Rapid
143	Tamarack (Larix laricina)	40-80(100)	20-30	1-2(3)	Moderate
144	Tanoak (Lithocarpus densiflora)	70-90(150)	30-50	1-3(7)	Moderate
145	Tupelo, black (Nyssa sylvatica)	50-80(100)	20-30	2-3(4)	Rapid
146	Tupelo, water (N. aquatica)	80-100(120)	20-30	3-4(5)	Rapid
147	Walnut, black (Juglans nigra)	50-90(150)	60-80	2-3(7)	Rapid
148	White-cedar, Atlantic (Chamaecyparis thyoides)	50-80(120)	10-20	1-2.5(5)	Slow
149	White-cedar, northern (Thuja occidentalis)	30-50(125)	5-10	2-3(6)	Slow
150	Willow, black (Salix nigra)	30-40(120)	20-30	1-2(6)	Rapid
151	Willow, peachleaf (S. amygdaloides)	20-40(60)	15-25	1-1.5(3)	Rapid
152	Yellow-poplar (Liriodendron tulipifera)	80-120(200)	30-40	2-5(12)	Rapid
153	Yew, Pacific (Taxus brevifolia)	20-40(65)	15-25	1-1.5(2)	Slow

/1/ Average range at maturity. Values for maximum height are enclosed in parentheses. /2/ Maximum crown spread of open-grown trees. Data primarily adapted and modified from Robinson, F. B., "Useful Trees and Shrubs." These values are not usually measured by foresters and may be more variable than the other data. They are presented here to show a general growth habit. /3/ Average range at maturity. Values for maximum diameter are enclosed in parentheses. Measurements at breast height (4.5 ft).

115. SIZE AND GROWTH RATE: TREES, SHRUBS

Data adapted from Robinson, F.B., "Useful Trees and Shrubs." Values are approximate because variations in soil, moisture, air circulation, and light conditions have marked effect on growth; data should be used with caution.

	Species	Height[1] ft	Spread[2] ft	Relative Growth Rate
1	Ailanthus (Ailanthus altissima)	50-60	35-45	Rapid
2	Alder (Alnus glutinosa)	35-50	25-30	Moderate
3	Alder (A. incana)	10-15	10-15	Rapid
4	Alder (A. rugosa)	15-25	15-20	Moderate
5	Aralia (Acanthopanax sieboldianus)	5-10	4-8	Moderate
6	Arborvitae (Thuja koraiensis)	8-15	3-5	Slow
7	Arborvitae (T. orientalis)	20-35	10-15	Rapid
8	Ash (Fraxinus excelsior)	80-100	65-90	Rapid
9	Barberry (Berberis thunbergi)	3-6	4-5	Slow
10	Basswood (Tilia cordata)	70-90	40-50	Slow
11	Beautyberry (Callicarpa japonica)	3-5	3-5	Moderate
12	Beautybush (Kolkwitzia amabilis)	5-10	8-10	Moderate
13	Beech (Fagus sylvatica)	80-100	50-70	Slow
14	Blackhaw (Viburnum prunifolium)	10-15	8-10	Moderate
15	Birch (Betula alba)	40-50	20-30	Rapid
16	Birch (B. nana)	3-5	3-5	Slow
17	Birch (B. pumila)	3-8	2-5	Slow
18	Buckeye (Aesculus parviflora)	5-10	8-12	Moderate
19	Buckthorn (Rhamnus cathartica)	8-12	10-12	Moderate
20	Buckthorn (R. frangula)	5-15	5-8	Moderate
21	Buttonbush (Cephalanthus occidentalis)	5-15	5-10	Moderate
22	Catalpa (Catalpa bignonioides)	30-50	20-40	Rapid
23	Catalpa (C. ovata)	15-25	12-18	Rapid
24	Cedar (Cedrus atlantica)	90-120	80-100	Moderate
25	Cedar (C. deodara)	140-170	100-120	Rapid
26	Cedar (C. libani)	75-120	80-100	Slow
27	Cedrela (Cedrela sinensis)	40-50	30-40	Rapid
28	Chaste-tree (Vitex agnus-castus)	15-20	8-12	Moderate
29	Cherry (Prunus avium)	35-50	20-30	Rapid
30	Cherry (P. cerasus)	20-30	15-20	Rapid
31	Chinquapin (Castanea pumila)	8-30	10-30	Rapid
32	Cherry-laurel (Prunus caroliniana)	20-40	15-20	Rapid
33	Chokeberry (Aronia arbutifolia)	6-10	4-6	Moderate
34	Chokeberry (A. melanocarpa)	4-6	2-3	Moderate
35	Chokecherry (Prunus virginiana)	15-25	10-20	Rapid
36	Clethra (Clethra alnifolia)	5-10	4-8	Moderate
37	Coralberry (Symphoricarpus vulgaris)	3-6	4-8	Rapid
38	Cork tree (Phellodendron amurense)	40-50	30-40	Moderate
39	Cork tree (P. sachalinense)	30-50	20-30	Rapid
40	Crab apple (Malus arnoldiana)	15-20	15-20	Rapid
41	Crab apple (M. baccata)	25-35	15-20	Rapid
42	Crab apple (M. coronaria)	20-25	20-25	Moderate
43	Crab apple (M. sargenti)	8-10	10-12	Moderate
44	Cryptomeria (Cryptomeria japonica)	70-100	30-35	Slow
45	Cypress (Cupressus macrocarpa)	45-65	30-40	Moderate
46	Cypress (C. sempervirens)	70-90	8-12	Slow
47	Devil's-walkingstick(Aralia spinosa)	20-30	10-15	Rapid
48	Dogwood (Cornus alba)	5-10	5-12	Slow
49	Dogwood (C. alternifolia)	15-25	20-40	Moderate
50	Dogwood (C. mas)	10-20	8-12	Moderate
51	Dogwood (C. sanguinea)	10-15	10-15	Moderate
52	Dogwood (C. stolonifera)	8-12	8-10	Slow
53	Elder (Sambucus canadensis)	5-15	5-12	Rapid
54	Elder (S. nigra)	10-15	10-15	Rapid
55	Elder (S. racemosa)	6-12	6-12	Rapid
56	Elm (Ulmus campestris)	90-120	50-60	Rapid
57	Elm (U. glabra)	80-100	50-65	Rapid
58	Elm (U. pumila)	30-60	20-40	Very rapid
59	Filbert (Corylus americana)	3-8	5-10	Rapid
60	Filbert (C. avellana)	15-25	15-20	Rapid
61	Fir (Abies homolepis)	40-50	20-25	Moderate
62	Fir (A. nordmanniana)	90-120	20-30	Moderate
63	Fir (A. veitchi)	70-80	25-35	Moderate
64	Fringetree (Chionanthus virginicus)	10-30	8-25	Slow
65	Ginkgo (Ginkgo biloba)	50-80	30-40	Slow
66	Goldenchaintree (Laburnum anagyroides)	20-25	15-20	Slow
67	Goldenraintree (Koelreuteria paniculata)	25-35	30-40	Slow
68	Hawthorn (Crataegus crus-galli)	25-35	20-30	Slow
69	Hawthorn (C. oxyacantha)	15-20	10-20	Moderate
70	Hawthorn (C. pedicellata)	10-20	10-20	Slow
71	Hawthorn (C. phaenopyrum)	15-25	20-25	Moderate
72	Hemlock (Tsuga caroliniana)	35-45	20-25	Moderate
73	Holly (Ilex aquifolium)	30-40	20-25	Slow
74	Holly (I. crenata)	5-12	8-12	Slow
75	Honeysuckle (Lonicera morrowi)	6-8	6-10	Rapid
76	Honeysuckle (L. tatarica)	10-12	10-12	Very rapid
77	Horsechestnut (Aesculus hippocastanum)	40-65	30-40	Moderate
78	Horsechestnut (A. pavia)	10-15	8-15	Rapid
79	Indigobush (Amorpha fruticosa)	5-10	6-12	Rapid
80	Inkberry (Ilex glabra)	8-12	10-12	Slow
81	Juniper (Juniperus chinensis)	15-20	2-4	Moderate
82	Juniper (J. sabina)	4-10	5-8	Slow

	Species	Height[1] ft	Spread[2] ft	Relative Growth Rate
83	Katsura tree (Cercidiphyllum japonicum)	20-40	30-40	Moderate
84	Larch (Larix decidua)	70-90	20-30	Rapid
85	Lead plant (Amorpha canescens)	2-4	3-4	Moderate
86	Leucothoe (Leucothoe catesbaei)	5-8	6-8	Slow
87	Magnolia (Magnolia soulangeana)	20-25	20-30	Moderate
88	Magnolia (M. stellata)	15-25	15-20	Slow
89	Magnolia (M. tripetala)	20-25	25-30	Moderate
90	Magnolia (M. virginiana)	20-30	10-15	Moderate
91	Maple (Acer ginnala)	12-20	8-12	Rapid
92	Maple (A. japonicum)	20-25	15-20	Slow
93	Maple (A. palmatum)	15-20	15-20	Slow
94	Maple (A. platanoides)	50-60	60-70	Rapid
95	Maple (A. pseudoplatanus)	60-70	50-60	Rapid
96	Maple (A. spicatum)	25-30	20-25	Moderate
97	Mountain-ash (Sorbus americans)	25-30	20-25	Rapid
98	Mountain-ash (S. aucuparia)	25-40	15-30	Moderate
99	Mountain-laurel (Kalmia latifolia)	8-15	8-10	Slow
100	Mulberry (Morus alba)	20-30	30-40	Rapid
101	Ninebark (Physocarpus opulifolius)	10-12	10-12	Rapid
102	Oak (Quercus robur)	60-90	60-80	Slow
103	Oregon grape (Mahonia aquifolium)	3-8	3-5	Moderate
104	Papaw (Asimina triloba)	15-30	15-25	Slow
105	Paulownia (Paulownia tomentosa)	40-50	30-40	Moderate
106	Pearshrub (Caragana arborescens)	10-20	6-18	Rapid
107	Photinia (Photinia villosa)	8-20	5-15	Moderate
108	Pine (Pinus bungeana)	70-90	45-55	Slow
109	Pine (P. cembra)	25-40	15-30	Very slow
110	Pine (P. nigra)	60-100	30-40	Rapid
111	Pine (P. sylvestris)	70-90	40-50	Rapid
112	Poplar (Populus alba)	80-100	50-70	Very rapid
113	Poplar (P. nigra)	50-60	60-70	Very rapid
114	Poplar (P. nigra italica)	35-50	5-10	Very rapid
115	Privet (Ligustrum amurense)	10-15	8-12	Rapid
116	Privet (L. ovalifolium)	15-25	10-15	Rapid
117	Privet (L. quihoui)	5-8	6-8	Moderate
118	Privet (L. vulgare)	15-20	15-20	Rapid
119	Quince (Cydonia oblonga)	4-8	6-10	Moderate
120	Redbud (Cercis canadensis)	25-40	25-35	Slow
121	Rhododendron (Rhododendron carolinianum)	4-6	4-5	Moderate
122	Rhododendron (R. catawbiense)	8-10	8-10	Moderate
123	Rhododendron (R. maximum)	10-15	10-15	Slow
124	Rhododendron (R. nudiflora)	5-10	3-6	Slow
125	Rhododendron (R. vaseyi)	8-15	6-10	Moderate
126	Rhododendron (R. viscosa)	3-8	3-8	Moderate
127	Russian-olive (Elaeagnus angustifolia)	15-25	30-35	Moderate
128	Saltbush (Baccharis halimifolia)	4-10	8-10	Rapid
129	Scholartree (Sophora japonica)	30-60	30-50	Rapid
130	Serviceberry (Amelanchier arborea)	20-40	10-15	Rapid
131	Serviceberry (A. laevis)	20-30	15-20	Rapid
132	Serviceberry (A. rotundifolia)	10-20	10-20	Rapid
133	Sheeplaurel (Kalmia angustifolia)	2-4	2-5	Slow
134	Silktree (Albizzia julibrissen)	25-35	30-40	Rapid
135	Smoke tree (Cotinus coggygria)	15-20	15-20	Slow
136	Snowberry (Symphoricarpus racemosus)	4-6	4-6	Rapid
137	Spicebush (Benzoin aestivale)	8-12	6-8	Slow
138	Spruce (Picea abies)	80-120	20-30	Rapid
139	Spruce (P. omorika)	70-90	20-25	Slow
140	Spruce (P. orientalis)	70-100	20-30	Slow
141	Sumac (Rhus aromatic)	5-10	6-12	Rapid
142	Sumac (R. copallina)	10-30	20-25	Rapid
143	Sumac (R. glabra)	10-15	10-15	Rapid
144	Sumac (R. typhina)	10-20	5-15	Rapid
145	Sweetshrub (Calycanthus floridus)	5-8	6-10	Moderate
146	Sycamore (Platanus orientalis)	60-70	50-60	Rapid
147	Viburnum (Viburnum rhytidophyllum)	8-12	8-12	Rapid
148	Viburnum (V. tomentosum)	8-10	8-10	Moderate
149	Wax myrtle (Myrica pensylvanica)	6-12	2-8	Slow
150	Wayfaring-tree (Viburnum lantana)	12-15	6-12	Moderate
151	White-cedar (Chamaecyparis obtusa)	70-80	20-30	Slow
152	White-cedar (C. pisifera)	100-120	10-20	Moderate
153	Willow (Salix alba vitellina)	40-70	30-40	Very rapid
154	Willow (S. babylonica)	30-40	30-40	Very rapid
155	Willow (S. Caprea)	15-20	10-15	Very rapid
156	Winterberry (Ilex verticillata)	5-10	3-5	Slow
157	Witch-hazel (Hamamelis japonica)	20-25	15-20	Slow
158	Witch-hazel (H. virginiana)	15-25	15-20	Slow
159	Yaupon (Ilex vomitoria)	10-15	5-8	Slow
160	Yellowroot (Zanthorhiza apiifolia)	2-4	3-5	Moderate
161	Yellowwood (Cladrastis lutea)	35-45	35-40	Moderate
162	Yew (Taxus baccata)	20-30	15-25	Very slow

/1/ Average height at maturity. /2/ Spread of crown when grown in open habitat.

116. MAXIMUM GROWTH RATE: PLANTS AND PLANT ORGANS

	Species	Material and Dimension	Growth Rate[1]	Time and Specification[2]	Maximum Size	Time and Specification[2]	Environmental Conditions: Location	Environmental Conditions: Special Factor
1	Nitella sp	Internodal cell, length	A: 1.7 mm/da	0-1 da after 0.4 mm	13 mm	10 da after 0.4 mm	Labo-	Mineral nutrient,
2			R-E: 1.1/da[3]	long		long	ratory	23-26°C, fluorescent light,
3	Phycomyces	Sporangiophore,	A: 3.0 mm/hr	Stage 4[4]			Labo-	Moist chamber,
4	blakesleeanus	length	R: 1/8 hr	Stage 4[4], 0.8 mm fr tip			ratory	22-25°C,
5	Daedalea quercina		A: 45 mg/da	0-8 da	482 mg	14 da		
6	Fromes gegtropus		A: 193 mg/da	0-7 da	1350 mg	7 da		
7	F. subroseus	Mycelial pellets,	A: 30 mg/da	1-8 da	298 mg	14 da	Labo-	70-ml shake culture,
8	Lentinus tingrinus	oven-dry weight	A: 140 mg/da	1-7 da	924 mg	7 da	ratory	optimal synthetic
9	L. trabea		A: 93 mg/da	0-7 da	652 mg	7 da		medium, 28°C,
10	Polyporus palustris		A: 60 mg/da	0-6 da	402 mg	14 da		inoculum 0.03 mg.
11	P. tulipiferus		A: 77 g/da	1-6 da	552 mg	14 da		
12	Trametes serialis		A: 112 mg/da	0-7 da	789 mg	7 da		
13	Bamboo (Dendrocala-mus sp)	Stem, length	A: 26.7 cm/da	1-2 mo after bud opening	14 m	2.5 mo after bud opening	Field	Daily fluctuating temp 23-32°C, daily rain,
14	Bamboo (Sinocalamus oldhami)	Stem, length	A: 31.4 cm/da[5] Sample averages: night, 0.97 cm/hr; day, 0.71 cm/hr	18 da after buds appeared above ground, height of 7 shoots of 1 plant, 3.2-7.7 m	Not reached at end of observations		Field	Sept 27-Oct 15, 1953; Cuba,
15	Barley	Kernel, length	A: 1.8 mm/da	3 da after pollination	9 mm	20 da after pollination	Field	Mean temp 26°C.
16	(Hordeum	Kernel, length	R: 0.35/da	2 da after pollination	9 mm	20 da after pollination		
17	sativum)	Kernel, fresh weight	A: 4.8 mg/da	6 da after pollination	57 mg	24 da after pollination		
18		Kernel, fresh weight	R: 0.5/da	2 da after pollination	57 mg	24 da after pollination		
19		Kernel, dry weight	A: 2.2 mg/da	12 da after pollination	32 mg	24 da after pollination		
20		Kernel, dry weight	R: 0.58/da	2 da after pollination	32 mg	24 da after pollination		
21		Plant, dry weight	A: 19.8 g/wk	13 wk after planting	122 g	16 wk after planting	Field	
22	Corn (Zea mays)		R: 1.37/wk	5 wk after planting				
23		Primary root, length	A: 2.6 mm/hr	2 da after soaking seed			Labo-	On moist filter paper,
24			E: 0.4/hr	2 da, 4mm from tip			ratory	25°C, in darkness.
25	Lily (Lilium	Flower bud, length	A: 11.5 mm/da	2 da before anthesis	155 mm	At anthesis	Green-	Daily fluctuating
26	longiflorum	Flower bud, length	R: 0.077/da	2-30 da before anthesis	155 mm	At anthesis	house	temp between
27	Floridii)	Anther, length	R: 0.088/da	20-30 da before anthesis	29 mm	At anthesis		means, 16-27°C.
28		Anther, fresh weight	R: 0.18/da	20-30 da before anthesis	160 mm	At anthesis		
29		Anther, dry weight	R: 0.18/da	20-30 da before anthesis	35 mg	9 da before anthesis		
30	Tobacco (Nicotiana tabacum)	Leaf, area	E: 0.85/da[6]	Leaf 8.6 cm long, 3 cm from base, 0.5 cm from midrib				
31	Tomato (Lycopersicon esculentum)	Stem, length	A: 29.3 mm/da	6 wk after planting			Labo-ratory	Daily alternation of 8 hr light, 26.5°C, and 16 hr dark, 17°C.

/1/ The growth curve of a plant or organ is frequently sigmoid in form with (1) an acceleration phase, (2) a short, or sometimes prolonged, linear phase, and (3) a final phase of deceleration. Absolute rates (A) pertain to phase 2 and are maximum rates. They are estimates of the instantaneous rate dX/dt, where X is the dimension measured and t is time. Relative rates (R) are estimated maximum values of $(1/X)(dX/dt)$, where X is the dimension measured and t is time. Relative elemental rate (E) pertains to an infinitesimal portion, or element, of length (dX), area (dA), et al., of the organ under consideration. The maximum relative elemental rate of growth of an organ therefore is the relative rate of growth of that infinitesimal portion which is growing most rapidly. For increase in a linear dimension, the relative elemental rate has the form $d(dX/dt)/dX$, and for increase in area $\partial(\partial X/\partial t)/\partial X + \partial(\partial Y/\partial t)/\partial Y$. /2/ Time growth rate and/or maximum size attained. For relative elemental rates (E), location within organ is specified. /3/ Growth is uniform over length of internodal cell; hence relative rate of elongation of cell as a whole equals relative elemental rate for each point. /4/ Stage of growth with formation of the sporangium. /5/ Average rate; 24.9 cm/da. /6/ Assuming that drawings of leaf (Avery, G.S., 1933) were made at weekly intervals.

117. GROWTH RATES: PLANT TISSUE CULTURES

	Tissue	Growth Period da	Initial Weight mg	Relative Increase W_1/W_0[1]	Relative Growth Rate $(100 r)^1$	Culture Medium[2]
	Artichoke (Helianthus tuberosus)					
1	Tuber	60	100	2.0	1.1	G
2	Tuber	60	100	5.4	2.8	G+0.3 mg/L IAA
3	Crown gall	60	100	5.1	2.7	G
4	Crown gall	60	100	4.5	2.5	G+0.3 mg/L IAA
5	Tuber	35	283	1.1	0.2	G
6	Tuber	35	247	1.9	1.8	G+0.3 mg/L IAA
7	Tuber	35	245	3.0	3.2	G+25% coconut milk
8	Tuber	35	237	4.4	4.2	G+100% coconut milk
	Carrot (Daucus carota)					
9		67	170	20.3	4.5	
10		0-7	170	2.0	9.9	
11	Root cambium	7-15	340	2.6	6.0	G+0.1 mg/L IAA
12		15-21	548	1.7	9.0	
13		21-41	941	2.0	3.3	
14		41-67	1852	2.1	2.7	
15		24	4.0	50	17	
16		0-2	4.0	1.2	7.0	
17		2-4	4.6	1.2	9.1	
18		4-6	5.6	1.6	22.9	
19		6-8	8.8	1.7	27	
20	Root phloem	8-10	15.1	2.0	34	W+15% coconut milk
21		10-12	30	1.9	32	
22		12-14	57	1.6	22.4	
23		14-16	92	1.6	22.4	
24		16-20	139	1.4	8.6	
25		20-24	197	1.2	4.3	

	Tissue	Growth Period da	Initial Weight mg	Relative Increase W_1/W_0[1]	Relative Growth Rate $(100 r)^1$	Culture Medium[2]
	Endive (Chicorium intybus)					
26	Tuber	60	100	3.7	2.2	G
27	Tuber	60	100	5.9	3.0	G+0.3 mg/L IAA
	Marigold (Tagetes erecta)					
28	Tumor	42	35	25	7.6	H
29	Tumor	42	35	29	8.0	H+0.5% dulcitol
30	Tumor	42	35	31	8.1	H+0.5% methanol
	Periwinkle (Vinca rosea)					
31	Tumor	42	35	12.7	6.1	H
	Potato (Solanum tuberosum)					
32	Tuber	35	3	55	11.1	W+6% coconut milk[3]
	Rutabaga (Brassica campestris)					
33	Root	60	100	4.1	2.4	G
34	Root	60	100	5.6	2.9	G+0.3 mg/L IAA
	Salsify (Scorzonera hispanica)					
35	Root	60	100	6.4	3.1	G
36	Root	60	100	9.4	3.7	G+1.0 mg/L IAA
37	Crown gall	42	100	8.8	3.6	G
38	Crown gall	35	100	9.2	3.7	G+1.0 mg/L IAA
	Snake palm (Amorphophallus riveri)					
39	Tuber	42	250	1.6	2.3	G+15% coconut milk
	Sunflower (Helianthus annuus)					
40	Crown gall	42	25	5.2	3.9	W_1
41	Crown gall	42	25	13.6	6.2	W_2
	Tobacco (Nicotiana, hybrid)[4]					
42	Stem	42	25	4.8	3.8	W_1
43	Stem	42	25	7.8	4.9	W_3

/1/ $W_1/W_0 = e^{rt}$, where W_0 is initial weight, W_1 is final weight, e is the base of natural log, r is the instantaneous growth rate expressed as per cent increase per day, and t is growth period in days. /2/ Abbreviations: G=Gautheret's agar; H=Hildebrandt et al.; W=White's liquid medium; W_1=White's agar; W_2= modified White's agar for tumorous tissue; W_3=modified White's agar for tobacco tissue; IAA = indoleacetic acid. /3/ Plus 2, 4-dichloro-phenoxyacetic acid, 18 mg/L. /4/ N. glauca x N. langsdorffii.

Part I: NUMBER, SIZE

	Species	Roots: Number[1]				Roots: Total Length, cm[1,2]				Root Hairs: Diameter, μ[1]			Root Hairs: Length, μ[1]		
		I	II	III	IV	I	II	III	IV	I	II	III	I	II	III
1	Equisetaceae: Equisetum (Equisetum arvense)									15	15		1200	1200	
2	Equisetum (E. kansanum)									13	13		1500	1500	
3	Pinaceae: Douglas-fir (Pseudotsuga menziesii)[3,4]	1	6.3	5.0	0.3	10,1	11.5	1.9	0.03	21.8	22.9	22.0	240	125	155
4	Juniper (Juniperus monosperma)[3,5]	1	3.4	2.0		4.8	6.4	0.8		14.9	15.3	14.0	70	84	56
5	Pine (Pinus ponderosa)[3,6]	1	15	70	12	100	505	465	23	24	26	22	140	155	240
6	Spruce (Picea englemanni)[3,7]	1	12	43	4.7	75	140	70	0.5	18	18	18	140	125	110
7	Typhaceae: Cattail (Typha latifolia)		25[8]							12				1200	
8	Gramineae: Bentgrass (Agrostis astoriana)									13	12	12	600	600	50
9	Bentgrass (A. tenuis)									10	10	10	400	400	300
10	Bermudagrass (Cynodon dactylon)	4	660	22		60	1980	9		12	8	8	970	270	260
11	Bluegrass (Poa pratensis)[9]	900	39700	43900		5490	26520	6100		11	9	7	1120	935	510
12	Fescue (Festuca commutata)									13	13	12	400	400	350
13	Foxtail grass (Setaria viridis)	12	3360			170	405			8	8		100	100	
14	Love grass (Eragrostis curvula)									8	8	8	270	270	200
15	Oat (Avena sativa)[10]	110	2190	2400		915	2440	1220		14	13	13	1400	1100	860
16	Rye (Secale cereale)[11]	130	3670	2600		1220	3960	1220		15	12	12	1720	940	590
17	Wheat (Triticum aestivum)[12]					2000	1230								
18	Wheatgrass (Agropyron elongatum)									12	12	12	800	750	750
19	Wheatgrass (A. palustris)									11	11	10	900	800	800
20	Amaranataceae: Amaranth (Amaranthus torreyi)	1	40	325	255	8	730	280	25		9	9		230	220
21	Leguminosae: Clover (Trifolium repens)	35	980	135		245	685	27		8	8	7	250	250	200
22	Honeylocust (Gleditsia triacanthos)										13	13		200	180
23	Kudzu vine (Pueraria hirsuta)	1	54	755		9	380	225		12	12	11	150	140	140
24	Parosela (Parosela dalea)	1	52	1560	1560	13	520	1560	310	15	15	150	110	110	90
25	Soybean (Glycine soja)	1	51	470	260	11	255	375	105	17	17	14	240	90	80
26	Umacaeae: Elm (Ulmus pumila)	1	55	1100	88000	55	2200	8800	176000		10				200
27	Hackberry (Celtis occidentalis)										8	8		170	170
28	Chenopodiaceae: Russian thistle (Salsola pestifer)	1	105	3150	630	35	1050	630	63		8	7		140	140
29	Caryophyllaceae: Grasswort (Cerastium arvense)	1	14	105		7	35	16		12	12	10	750	600	600
30	Cruciferae: Descurainia (Descurainia pinnata)	1	10	520	1560	5	130	1040	470	7	7	6	350	300	210
31	Capparidaceae: Cleome (Cleome serrulata)											6			150
32	Zygophyllaceae: Tribulus (Tribulus terrestris)	1	200	160		25	160	32			7	7		140	130
33	Euphorbiaceae: Euphorbia (Euphorbia albomarginata)	1	22	220		11	220	155		9	8	8	300	240	240
34	Umbelliferae: Sium (Sium suave)									8	8		150	150	
35	Oleaceae: Ash (Fraxinus lanceolata)										5	5		370	370
36	Convolvulaceae: Bindweed (Convolvulus arvensis)	1	28	170		14	335	32			14	14		90	80
37	Labiatae: Catnip (Nepeta cataria)	1	100	1200	200	10	300	600	20	8	8	8	410	390	340
38	Solanaceae: Nightshade (Solanum eleagnifolium)	1	130	650		65	650	325			7	7		120	110
39	Bignoniaceae: Catalpa (Catalpa bignonioides)										10	10		250	250
40	Plantaginaceae: Plantain (Plantago major)	26	635	1450		275	1150	435		12	10	10	220	210	200
41	Compositae: Dandelion (Taraxacum officinale)	1	180	900		30	720	360			7	7		130	130
42	Marigold (Tagetes patula)	72	1	430		12	110	130		14	14	14	180	160	140

/1/ I = main roots, i.e., roots arising directly from base of plant, may be seminal or adventitious; II = secondary roots, i.e., roots arising directly from main roots; III = tertiary roots, i.e., roots arising directly from secondary roots; IV = quaternary roots, i.e., roots arising directly from tertiary roots. /2/ Total length of roots in the specified categories refers to their combined lengths. /3/ Data applicable to seedlings, 6 months old. /4/ Total surface area of roots, 300 sq mm; total surface area of root hairs, 54 sq mm. /5/ Total surface area of roots, 1830 sq mm; total surface area of root hairs, 27 sq mm. /6/ Total surface area of roots, 1350 sq mm; total surface area of roots hairs, 180 sq mm. /7/ Total surface area of roots, 260 sq mm; total surface area of root hairs, 110 sq mm. /8/ Per cm of main roots. /9/ Total surface area of roots, 2200 sq cm; total volume, 13900 cu mm; total surface area of root hairs, 15780 sq cm; number of root hairs in a core of soil 3 inches in diameter and 6 inches deep, 51.5 million. /10/ Surface area of roots, 320 sq cm; total volume, 2610 cu mm; surface area of root hairs, 3440 sq cm; number of root hairs in a core of soil (cf Fn 9), 6.3 million. /11/ Surface area of roots, 505 sq cm; total volume, 4580 cu mm; surface area of root hairs, 7680 sq cm; number of root hairs in a core of soil (cf Fn 9), 12.5 million. /12/ Surface area of roots, 310 sq cm.

Part II: EXTENT

	Species	Location and Soil Type	Age	Condition of Growth	Extent of Roots			
					Depth		Spread	
					cm	ft	cm	ft
1	Alfalfa (Medicago sativa)	Nebr.; alluvial silt loam.	2 yr		366	12	<30	<1
2	Apple (Pyrus malus)	N.Y.; heavy clay.	15 yr		>152	>5	>396	>13
3	Apple (P. malus)	Nebr.; porous loess.	3 yr			14-16		7-10
4			17 yr			30-35		215
5	Apricot (Prunus armeniaca)[1]	Okla.; silt loam over clay.			244	8	975	32
6	Asparagus (Asparagus officinalis)	Nebr.; silt loam over clay.	6 yr		305	10	122	4
7	Bean, kidney (Phaseolus vulgaris)	Nebr.; silt loam over clay.	2.5 mo	Mature pods.	137	4.5	61	2
8	Beet, garden (Beta vulgaris)	Nebr.; silt loam over clay.	3.5 mo	Edible roots.	305	10	122	4
9	Cabbage (Brassica oleracea capitata)	Nebr.; silt loam over clay.	4 mo	Mature heads.	238	7.8	107	3.5
10	Corn (Zea mays)	Nebr.; silt loam underlain by loess.	4 mo	Mature.	250	8.2	122	4
11	Lettuce (Lactuca sativa)	Nebr.; silt loam over clay.	3 mo	Flowering.	183	6	40	1.5
12	Oak, bur (Quercus macrocarpa)	Nebr.; silt loam.	>65 yr[2]		>305	>10	1829	60
13	Oat (Avena sativa)	Nebr.; silt loam underlain by loess.	3 mo	Grain maturing.	207	6.8	40	1.3
14	Peach (Prunus persica)	Ga.; sandy top soil, clay subsoil.	2 yr		91	3	183	6
15	Pecan (Carya illinoensis)	Ga.; sandy top soil, clay subsoil.	6 yr		183	6	732	24
16	Pine, pitch (Pinus rigida)	N.Y.; sandy soil	30 yr		274	>9	975	323
17	Potato (Solanum tuberosum)	Nebr.; silt loam underlain by loess.	3 mo	Mature tubers.	143	4.7	64	2.1
18	Squash (Cucurbita maxima)	Nebr.; silt loam over clay.	2.6 mo	Fruiting.	183	6	579	19
19	Tomato (Lycoperaicon esculentum)	Nebr.; silt loam over clay.	4 mo	Fruiting.	137	4.5	168	5.5
20	Wheat (Triticum aestivum)	Nebr.; silt loam underlain by loess.	3 mo	Mature grain.	204	6.7	40	1.3

/1/ Seedling. /2/ Height of tree, 37.5 ft. /3/ Range, 30-35 ft.

119. INTERCELLULAR SPACE: LEAVES

Between the upper and lower epidermis of a leaf are numerous intercellular spaces or air chambers constituting a connected system throughout the leaf. Values are volume of intercellular space expressed as per cent of total volume of leaf and, unless otherwise specified, are applicable to mature leaves of plants grown out-of-doors in full sunlight. Values for leaves in shade are enclosed in parentheses.

	Species	Volume, %	Method[1]
1	Alfalfa (Medicago sativa), early spring leaf	29	C
2	Alfalfa (M. sativa), late spring leaf	27	C
3	Alfalfa (M. sativa), secondary leaf	26	C
4	Alfalfa (M. sativa), tertiary leaf	23	C
5	Alfalfa (M. sativa), quaternary leaf	19	C
6	Amaryllis (Amaryllis curvifolia)	36	W
7	Anthropodium (Anthropodium paniculatum)	14	W
8	Anthurium (Anthurium digitatum)	12	W
9	Apple, delicious (Pyrus malus)	35	C
10	Apple, liveland (P. malus)	34	C
11	Arctocalyx (Arctocalyx endlicherianus)	8.4	W
12	Ardisia (Ardisia crenulata)	22	W
13	Aristolochia (Aristolochia labiosa)	30	W
14	Arum (Arum maculatum)	57	W
15	Ash (Fraxinus excelsior), inner leaf	(28)	T
16	Ash (F. excelsior), peripheral leaf	19(21)	T
17	Aster (Aster scaber)	(41)	W
18	Aucuba (Aucuba japonica)	27	W
19	Banana (Musa paridisiaca sapientum)	25-48	W
20	Barberry (Berberis nervosa)	(36)	C
21	Basswood (Tilia cordata), mature leaf	20(26)	T
22	Basswood (T. cordata), immature leaf	3.5(4)	T
23	Bean (Phaseolus sp), dry habitat	19	T
24	Bean (Phaseolus sp), moist habitat	27	T
25	Beech (Fagus sylvatica), mature leaf	22(28)	T
26	Beech (F. sylvatica), immature leaf	5(6)	T
27	Beech (F. sylvatica), inner leaf	(32)	T
28	Beech (F. sylvatica), peripheral leaf	(29)	T
29	Begonia (Begonia hydrocotylifolia)	3.5	W
30	Begonia (B. incarnata)	19	W
31	Bergenia (Bergenia cordifolia), dried leaf[2]	26	W
32	Bergenia (B. cordifolia), greenhouse[3]	26	W
33	Bloodflower (Hasmanthus coccineus)	21	W
34	Bocconia (Bocconia frutescens)	27	W
35	Bougainvillea (Bougainvillea glabra)[3]	19	T
36	Boxwood (Buxus sempervirens)	19	T
37	Cacalia (Cacalia delfnifolia)	(35)	W
38	Camellia (Camellia japonica)	22;29	W;C
39	Camphortree (Camphora officinalis)	7.7	W
40	Canna (Canna tubiflora)	15	W
41	Cassine (Cassine maurocenia), dried leaf[2]	17	W
42	Cassine (C. maurocenia), greenhouse[3]	17	W
43	Catalpa (Catalpa speciosa), large leaf	32	C
44	Catalpa (C. speciosa), medium leaf	43	C
45	Catalpa (C. speciosa), small leaf	(31)	C
46	Cestrum (Cestrum laurifolium)	40	W
47	Chirita (Chirita sinensis)	14	W
48	Chrysanthemum (Chrysanthemum morifolium)[3]	28	W
49	Coprosma (Coprosma bauerl)[3]	20	W
50	Corn (Zea mays)	28	C
51	Dahlia (Dahlia variabilis)	23	W
52	Dipteracanthus (Dipteracanthus schauerianus)	29	W
53	Drimys (Drimys sp), dried leaf[2]	19	W
54	Drimys (Drimys sp), in greenhouse[3]	25	W
55	Dogwood (Cornus sanguinea), mature leaf	21(29)	T
56	Dogwood (C. sanguinea), immature leaf	9(12)	T
57	Elder (Sambucus nigra)	20	T
58	Elder (S. sieboldiana)	(24)	W
59	Englisb-daisy (Bellis perennis)	23	T
60	Epimedium (Epimedium pubigerum)	19	T
61	Eucalyptus (Eucalyptus globulus)	30	C
62	Euonymus (Euonymus americanus)	24	T
63	Euonymus (E. japonicus)	23	W
64	Ficus (Ficus oppositifolia)	20	W
65	Filbert (Corylus tubulosa), mature leaf	17(33)	T
66	Filbert (C. tubulosa), immature leaf	7(11)	T
67	Flowering-maple (Abutilon theophrasti)	33	C
68	Garlic (Allium ursinum), dried leaf[2]	20	W
69	Garlic (A. ursinum), in greenhouse[3]	52	W
70	Garlic (A. ursinum), in field	66	W
71	Gentian (Gentiana tubelica)	41	W
72	Ginkgo (Ginkgo biloba)	41	C
73	Globedaisy (Globularia incanescens)	25	T
74	Glorybird (Calystegia soldanella)	37	W
75	Goldenrod (Solidago sempervirens)	53	W
76	Granadilla (Passiflora quadrangularis)	21	W
77	Grape, European (Vitis vinifera)	13	T
78	Grape, riverbank (V. vulpina)	25	C
79	Grapefruit (Citrus grandis)	23	C
80	Greenbrier (Smilax maritanica)	23	W
81	Guevina (Guevina avellana), dried leaf[2]	45	W
82	Guevina (G. avellana), in greenhouse[3]	50	W
83	Hepatica (Hepatica angulosa)	25	T
84	Honeysuckle (Lonicera tartarica)	10	T
85	Hopseedbush (Dodonaea viscosa), in greenhouse	14	W
86	Horsechestnut (Aesculus rubicunda), mature leaf	26(23)	T
87	Horsechestnut (A. rubicunda), immature leaf	6(6)	T
88	Horsechestnut (A. rubicunda), inner leaf	(18)	T
89	Horsechestnut (A. rubicunda), peripheral leaf	(33)	T
90	Ivy, English (Hedera helix)	30;24	W;T
91	Jewelweed (Impatiens sp), in dry habitat	34	T
92	Jewelweed (I. sp), in moist habitat	49	T
93	Katsura tree (Cercidiphyllum japonicum), mature leaf	18(26)	T
94	Katsura tree (C. japonicum), immature leaf	6(6)	T
95	Laurelcherry (Prunus laurocerasus)	29	W
96	Leopardbane (Doronicum sp), dried leaf[2]	22	W
97	Leopardbane (Doronicum sp), in greenhouse[3]	59	W
98	Leopardbane (Doronicum sp), in field	71	W
99	Life-plant (Bryophyllum calycinum), in greenhouse	17	C
100	Ligularia (Ligularia tibetica)	54	W
101	Ligularia (L. hessiliganea)	(43)	W
102	Lilac (Syringa vulgaris), mature leaf	20(28)[4]	T
103	Lilac (S. vulgaris), immature leaf	9(10)	T
104	Lily (Lilium candidum)	20	T
105	Loosestrife (Lysimachia ciliata), dried leaf[2]	24	W
106	Loosestrife (L. ciliata), in greenhouse[3]	31	W
107	Loosestrife (L. ciliata), in field	59	W
108	Loosestrife (L. clethroides)	(33)	W
109	Mahonia (Mahonia aquifolium)	18	W
110	Maple (Acer pseudoplatanus)	25	T
111	Marlea (Marlea platanifolia)	(25)	W
112	Nasturtium (Tropaeolum sp), dry habitat	17	T
113	Nasturtium (Tropaeolum sp), moist habitat	35	T
114	New Zealand spinach (Tetragonia expansa)	22;18	W;C
115	Oak (Quercus coccinea), mature leaf	24(33)	T
116	Oak (Q. coccinea), immature leaf	8(8)	T
117	Oleander (Nerium oleander), top leaf[5]	30	C
118	Oleander (N. oleander), bottom leaf[6]	34	C
119	Oleander (N. oleander), top leaf[5]	27	C
120	Oleander (N. oleander) bottom leaf[6]	42	C
121	Orange (Citrus sinensis)[3]	29	W
122	Paspalum (Paspalum setaceum)	6.8	W
123	Pear (Pyrus communis)	13(22)	T
124	Pentstemon (Pentstemon barbatus)	20	T
125	Periwinkle (Vinca minor)	23	W
126	Peteria (Peteria ramentacea)	20	T
127	Photinia (Photinia glabra), old leaf	22(26)	W
128	Photinia (P. glabra), young leaf	24(27)	W
129	Pistia (Pistia texensis)	71	W
130	Plantain-lily (Hosta japonica)	28	W
131	Plectranthus (Plectranthus fruticosus)	18	W
132	Psidium (Psidium cuneatum)	16	W
133	Redbud (Cercis canadensis)	32	C
134	Rhododendron (Rhododendron oreodoxum)	23	T
135	Sagittaria (Sagittaria trifolia)	36;39	W;C
136	Sarcococca (Sarcococca pruniformis)	17	W
137	Saxifraga (Saxifraga stolonifera)	39	W
138	Sedum (Sedum sieboldii)	(28)	W
139	Sedum, stone crop (S. viride)	(43)	W
140	Senecio (Senecio doria)	58	W
141	Senecio (S. nemorensis)	64	W
142	Solanum (Solanum serpentinum)	25	W
143	Sorrel (Rumex acetosa)	27(30)	W
144	Sowthistle (Sonchus oleraceus)	27	W
145	Sycamore (Platanus occidentalis), inner leaf	(27)	T
146	Sycamore (P. occidentalis), peripheral leaf	(31)	T
147	Tobacco (Nicotiana tabacum)	26	W
148	Tovara (Tovara filiformis)	28(34)[7]	W
149	Turnip (Brassica rapa)	18	W
150	Valerian (Valeriana officinalis)	(30)	W
151	Violet (Viola mandschurica)	23(20)	W
152	Violet (V. rossii)	27	W
153	Walnut (Juglans regia), inner leaf	(25)	T
154	Walnut (J. regia), peripheral leaf	18(21)	T
155	Waterchestnut (Trapa natans)	20	W
156	Wax-plant (Hoya carnosa)	14	W

/1/ Methods of determination: W = measurement made by infiltrating intercellular space with water; C = measurement made on camera lucida drawings of leaf sections; T = measurement by infiltrating intercellular space with turpentine. /2/ Leaf dried 30 min prior to measurement. /3/ In greenhouse, plants growing in well-watered and well-lighted conditions. /4/ Measurements made on camera lucida drawings: in sun, 21%; in shade, 24%. /5/ Plants under artificial light of 175 ft-candles. /6/ Plant under artificial light of 77 ft-candles. /7/ Measurements made on camera lucida drawings: in sun, 33%; in shade, 39%.

120. DISTRIBUTION AND SIZE OF STOMATA: LEAVES

Stomata are pores through which occur gaseous diffusion. Values for upper leaf surface are followed by those for lower surface. Number of stomata are per sq cm of leaf surface.

	Species	No. /sq cm	Pore Size μ[1]		Species	No. /sq cm	Pore Size μ[1]
1	Abronia (Abronia villosa)[2]	20,000;20,000		36	Mulberry (Morus alba)	0;48,000	
2	Acacia (Acacia aneura)	11,200;11,200		37	Nasturtium (Tropaeolum majus)	0;13,000	;12x6
3	Ailanthus (Ailanthus altissima)	0;38,600		38	Nightshade (Solanum dulcamara)	6,000;26,300	
4	Alfalfa (Medicago sativa)	16,900;13,800		39	Oat (Avena sativa)	2,500;2,300	31x7;38x8
5	Apple, delicious (Pyrus malus)	0;29,400		40	Oak, English (Quercus robur)	0;45,000[5]	
6	Apple, Grimes golden (P. malus)	0;41,200		41	Oak, scarlet (Q. coccinea)	0;103,800	
7	Avens (Geum parviflora)	7,500;23,000		42	Oak, Spanish (Q. triloba)	0;119,200	;9x1
8	Barberry (Berberis vulgaris)	0;40,000		43	Parafoxia (Parafoxia linearis)[2]	22,000;23,600	
9	Barley (Hordeum vulgare)	5,500;5,400		44	Pea, garden (Pisum sativum)	10,100;21,600	
10	Basswood (Tilia vulgaris)	0;13,000		45	Peach (Prunus persica)	0;22,500	
11	Bean (Phaseolus vulgaris)	4,000;28,100	8x3;7x3	46	Plantain (Alisma plantago-aquatica)	5,000;3,600	
12	Begonia (Begonia coccinea)	0;4,000	;21x8	47	Plantain (Plantago triandra)	15,500;20,000	
13	Brachycome (Brachycome sinclairii)	22,000;15,000		48	Poplar, black (Populus nigra)	2,000;11,500	
14	Cabbage (Brassica oleracea cap.)	14,100;22,600		49	Potato (Solanum tuberosum)	5,100;16,100	
15	Castor bean (Ricinus communis)	6,400;17,600	8x4;10x4	50	Primrose (Oenothera deltoides)[2]	17,300;17,300	
16	Cherry (Prunus cerasus)	0;24,900		51	Rye (Secale cereale)	5,100;46,000	
17	Coleus (Coleus blumei)	0;14,100	;10x5	52	Salt-bush (Atriplex vesicarium)	12,000;12,000	
18	Corn (Zea mays)	5,200;5,600	19x4;19x5	53	Scilla (Scilla mutans) dry atmos.	5,900;4,950[5]	
19	Coach-whip (Fouqueria splendens)[2]	7,100;7,100		54	Scilla (S. mutans), moist atmos.	2,750;2,400[5]	
20	Cucumber (Cucumis sativus)	22,100;44,200		55	Sorrel, wood (Oxalis acetosella)	0;5,600	
21	Elder (Sambucus nigra), in sun	0;4,000-26,000		56	Soybean (Glycine soja)	14,700;16,600	
22	Elder (S. nigra), in shade	0;1,200-14,000		57	Spearwort (Ranunculus lingua)	1,300;2,700	
23	Ficaria (Ficaria verna), in sun	1,850;4,250[3]		58	Speedwell (Veronica fruticulosa)	22,400;18,600	
24	Ficaria (F. verna), in shade	2,700;4,900[4]		59	Stitchwort (Malachium aquatica)	3,100;5,400	
25	Forget-me-not(Myosotis scorpioides)	700;9,100		60	Sunflower (Helianthus annuus)	8,500;15,600	18x8;22x8
26	Frogbit (Hydrocharis morsus-ranae)	8,900;0		61	Sun-rose (Helianthemum alpestre)	28,600;20,400	
27	Geranium (Pelargonium domesticum)	1,900;5,900	23x8;24x9	62	Sycamore (Platanus occidentalis)	0;27,800	
28	Globedaisy (Globularia nudicaulis)	8,800;35,700		63	Tomato (Lycopersicon esculentum)	1,200;13,000	10x5;13x6
29	Groundsel (Senecio cottenii)	0;51,200		64	Walnut, black (Juglans nigra)	0;46,100	
30	Holly, American (Ilex opaca)	0;17,000	;12x6	65	Wandering-jew (Zebrina pendula)	0;1,400	;31x12
31	Ivy, English (Hedera helix)	0;15,800	;11x4	66	Water-soldier (Stratiotes aloides)	3,800;6,900	
32	Jimson weed (Datura stramonium)	11,400;18,900		67	Water lily (Nymphaea alba)	46,000;0	
33	Lilac (Syringa vulgaris)	0;33,000		68	Water lily (N. thermalis)	62,500;0	
34	Lychnis (Lychnis alpina)	15,600;14,600		69	Wheat (Triticum aestivum)	3,300;1,400	40x7;38x7
35	Marsh marigold (Caltha palustris)	0;4,000		70	Yew, English (Taxus baccata)	0;11,500	

/1/ Pore fully open. /2/ In desert. /3/ Average of 900-2800 (upper); 2800-5700 (lower). /4/ Average of 1000-4400 (upper); 2800-7000 (lower). /5/ Additional species not listed in table: black oak (Q. velutina), 58,000; northern red oak (Q. rubra), 68,000; willow oak (Q. phellos), 72,000. (Upper surface for all, 0.) /6/ Average of 1100-9900 (upper); 900-9000 (lower). /7/ Average of 1100-4400 (upper); 1300-3500 (lower).

121. RATIO OF INTERNAL TO EXTERNAL SURFACE: LEAVES

Between the upper and lower epidermis of a leaf are layers of mesophyll cells surrounded by intercellular spaces. The internal suface (I), of the leaf consisting of all the mesophyll surfaces in contact with intercellular spaces, is much larger than the external surface (E), formed by the two epidermal layers. The ratio presented is that of total internal surface to total external (both upper and lower surfaces). Values are applicable to leaves of plants grown in full sunlight; those for leaves in shade are enclosed in parentheses.

	Species	Surface Ratio I:E		Species	Surface Ratio I:E
1	Alfalfa (Medicago sativa), early spring leaf	15	16	Coleus (Coleus blumei)	4.6
2	Alfalfa (M. sativa), late spring leaf	14	17	Eucalyptus (Eucalyptus globulus)	31
3	Alfalfa (M. sativa), secondcry leaf	11	18	Flowering-maple (Abutilon theophrasti)	11
4	Alfalfa (M. sativa), tertiary leaf	10	19	Gaultheria (Gaultheria shallon)	(8.2)
5	Alfalfa (M. sativa), quaternary leaf	9.9	20	Grape, riverbank (Vitis vulpina)	12
6	Apple, delicious (Pyrus malus)[1]	24	21	Grapefruit (Citrus grandis)	17
7	Apple, liveland (P. malus)[1]	23	22	Holly, American (Ilex opaca)	(13)
8	Apple, Jonathan (P. malus)[2]	14	23	Lemon (Citrus limonia)	22
9	Apple, wealthy (P. malus)[2]	15	24	Life-plant (Hrysophyllum caliycynum)	7. 9
10	Apple, York (P. malus)[2]	12	25	Lilac (Syringa vulgaris)	13(6.8)
11	Barberry (Berberis nervosa)	(9.9)	26	Oleander (Nerium oleander)	20
12	Castor bean (Ricinus communis)	(13)	27	Redbud (Cercis canadensis)	16
13	Catalpa (Catalpa speciosa), leaf large	19	28	Sumac (Rhus glabra)	16
14	Catalpa (C. speciosa), leaf medium	14	29	Tobacco (Nicotiana tabacum)	7. 1
15	Catalpa (C. speciosa), leaf small	(9.3)			

/1/ Twenty-year-old tree. /2/ Two-year-old tree.

122. SURFACE AREA AND NUMBER: LEAVES

Values for needle leaves, indicated by an asterisk (*), represent the entire surface; values for flat leaves must be multiplied by 2 to obtain the entire externally exposed leaf surface (both upper and lower).

Part I: SURFACE AREA PER LEAF

	Species	Leaf Surface sq cm/leaf[1]		Species	Leaf Surface sq cm/leaf[1]
1	Alfalfa (Medicago sativa), early spring leaf	2	43	Lemon (Citrus limonia)	37-40
2	Alfalfa (M. sativa), late spring leaf	2	44	Lime (C. aurantifolia)	13-14.5
3	Alfalfa (M. sativa), secondary leaf	1.2	45	Kumquat (Fortunella margarita)	9
4	Alfalfa (M. sativa), tertiary leaf	0.6	46	Maple (Acer saccharum)	73
5	Alfalfa (M. sativa), quaternary leaf	0.4	47	Milkweed (Asclepias arenaria)	48
6	Apple, laxton (Pyrus malus)	18	48	Musa (Musa acuminata)	0.7-2 sq m
7	Atalantia (Atalantia citroides)	9	49	Morning glory (Ipomoea purpurea), 1st leaf	35
8	Atalantia (A. disticha)	3	50	Morning glory (I. purpurea), 3rd leaf	50
9	Balsamocitrus (Balsamocitrus gabonensis)	12	51	Morning glory (I. purpurea), 5th leaf	80
10	Banana (Musa paradisiaca sapientum)	2700-5200	52	Morning glory (I. purpurea), 7th leaf	100
11	Basswood (Tilia americana)	73	53	Oleander (Nerium oleander), 300 ft-c	10.5
12	Bean (Phaseolus vulgaris), 15 da old	49	54	Oleander (N. oleander), 86 ft-c	11
13	Beech (Fagus sp)	22[2]	55	Orange (Citrus sinensis), 3 yr old	3-130
14	Box-orange (Severinia buxifolia)	3.5	56	Orange (C. sinensis), 29 yr old	2-48
15	Catalpa (Catalpa speciosa), small leaf	29-71	57	Pepperweed (Lepidium alyssoides)	5
16	Catalpa (C. speciosa), medium leaf	135	58	Periwinkle (Vinca rosea), 300 ft-c	4.5
17	Catalpa (C. speciosa), large leaf	240-380	59	Periwinkle (V. rosea), 86 ft-c	4
18	Cherry-orange (Citropsis schweinfurthii)	10		Pine (Pinus banksiana), 36 yr old	
19	Citron (Citrus medica)	20-33	60	Unthinned forest	52.4 sq mm*
20	Clappia (Clappia suffruticosa)	0.7	61	Heavily thinned	51.6 sq mm*
21	Coldenia (Coldenia hispidissima)	0.2	62	Moderately thinned	49.7 sq mm*
22	Corn (Zea mays)	600-1320	63	Pine (P. contorta), dry habitat	128 sq mm*
23	Cottonwood (Populus fremontii wislizenii)	50	64	Pine (P. contorta), moist habitat	232 sq mm*
24	Crownbeard (Verbesina encelioides)	12	65	Pine (P. resinosa), 27 yr old	401 sq mm*
25	Cucumber (Cucumis sativus), cotyledons	15	66	Pine (P. strobus), 27 yr old	122 sq mm*
26	Cucumber (C. sativus), 1st leaf	18	67	Pummelo (Citrus grandis)	40
27	Cucumber (C. sativus), 2nd leaf	29	68	Ragweed (Ambrosia trifida)	100
28	Cucumber (C. sativus), 3rd leaf	33	69	Redbud (Cercis canadensis)	65
29	Date (Phoenix dactylifera), 12 yr old	43,700	70	Saltbush (Atriplex canescens)	1
30	Desert-lime (Eremocitrus glauca)	60 sq mm	71	Seepweed (Suaeda suffrutescens)	59 sq mm
31	Elm (Ulmus americana)	54	72	Spruce (Picea engelmannii), dry habitat	44 sq mm*
32	Fingerlime (Microcitrus australasica)	40 sq mm	73	Spruce (P. engelmannii), moist habitat	69 sq mm*
33	Fir (Abies lasiocarpa), moist habitat	80 sq mm*	74	Sumac (Rhus trilobata)	21
34	Fir (A. lasiocarpa), dry habitat	55 sq mm*	75	Sunflower (Helianthus annuus)	38
35	Frankenia (Frankenia jamesii)	0.2	76	Tabog (Chaetospermum glutinosum)	8.6
36	Gooseberry (Ribes rotundifolium)	2-16.5	77	Taro (Colocasia antiquorum)	9100
37	Gourd (Cucurbita foetidissima)	560	78	Trifoliate-orange (Poncirus trifoliata)	5
38	Grape, malaga (Vitis vinifera)	125-150	79	Wheat (Triticum aestivum), 1st leaf[3]	5
39	Grape, muscat (V. vinifera)	88	80	Wheat (T. aestivum), 3rd leaf[3]	13
40	Grapefruit (Citrus paradisi)	40-45	81	Wheat (T. aestivum), 5th leaf[3]	15
41	Greggia (Greggia camporum)	2	82	Yellow-poplar (Liriodendron tulipifera)	130
42	Groundsel (Senecio spartioides)	5	83	Zinnia (Zinnia grandiflora)	0.8

/1/ Values are sq cm unless otherwise specified. /2/ Calculated. /3/ Plants under artificial light, 600 ft-c.

Part II: NUMBER OF LEAVES AND TOTAL LEAF SURFACE AREA PER PLANT

	Species	Leaves			Species	Leaves	
		no./plant	sq cm/plant			no./plant	sq cm/plant
1	Alfalfa (Medicago sativa)	88[1]	16,000	32	Orange (Citrus sinensis), 29 yr old	172,613	2,000,000
2	Apple (Pyrus malus), 2 yr old		11,000	33	Peach (Prunus persica), 5 yr old[3]		922,000
3	Apple (P. malus), 5 yr old		294,000	34	Peach (P. persica), 5 yr old[4]		750,000
4	Apple (P. malus), 9 yr old	20,000	318,000	35	Pepperweed (Lepidium alyssoides)	1318[2]	6700
5	Barley (Hordeum vulgare), 49 da old		900	36	Periwinkle (Vinca rosea), 86 ft-c	163	630
6	Bean (Phaseolus vulgaris), 15 da old	2	98	37	Periwinkle (V. rosea), 300 ft-c	257	1150
7	Beech (Fagus sp), in forest	35,000	780,500[2]		Pine (Pinus banksiana), 36 yr old		
8	Beech (Fagus sp), in open field	200,000	4,460,000[2]	38	Unthinned forest	744,924	390,000*[5]
9	Beet, mangold (Beta vulgaris)		3050	39	Heavily thinned	1,628,022	840,000*[5]
10	Beet, sugar (B. vulgaris)		4080	40	Moderately thinned	891,211	443,000*[5]
11	Catalpa (Catalpa speciosa)	26,024	1,952,000	41	Pine (P. ponderosa), 2 yr old		7240
12	Coldenia (Coldenia hispidissima)	11,560[2]	2300	42	Pine (P. resinosa), 27 yr old, 2x2[6]	19,439	77,900*
13	Corn (Zea mays)		7900	43	Pine (P. resinosa), 27 yr old, 4x4[6]	51,060	205,000*
14	Cotton (Gossypium sp)		535-1200	44	Pine (P. strobus), 27 yr old, 2x2[6]	121,805	149,000*
15	Crowbeard (Verbesina encelioides)		560	45	Pine (P. strobus), 27 yr old, 4x4[7]	186,644	228,000*
16	Cucumber (Cucumis sativus), 135 ft-c		16	46	Potato (Solanum tuberosum)		17,800
17	Cucumber (C. sativus), 270 ft-c		18	47	Raspberry (Rubus occidentalis), shoot		13,100
18	Cucumber (C. sativus), full sun		180-1100	48	Raspberry (R. occidentalis), fruiting cane		16,300
19	Date (Phoenix dactylifera), 12 yr old	120	525 sq m	49	Saltbush (Atriplex canescens)		47,000
20	Fir (Abies alba), trunk diameter 40 cm	15,000,000		50	Seepweed (Suaeda suffrutescens)		3210
21	Fir (A. pectinata)		12,000*	51	Sorghum, red amber (Sorghum vulgare)		4840
22	Frankenia (Frankenia jamesii)	9487[2]	2182	52	Spruce (Picea sp), 4 yr old	6577	550*
23	Gourd (Cucurbita foetidissima)	1617[2]	911,976		Strawberry (Fragaria chiloensis)		
24	Grape, malaga (Vitis vinifera)	32	4000-4900	53	Dunlap, with runners		1440
25	Grape, muscat (V. vinifera)	26	2300-2400	54	Dunlap, without runners		896
26	Milkweed (Asclepias arenaria)	36	1700	55	Strawberry (F. virginiana)		350
27	Morning glory (Ipomoea purpurea)	9[2]	750	56	Sumac (Rhus trilobata)	3000[2]	63,240
28	Oleander (Nerium oleander), 86 ft-c	24	268	57	Sunflower (Helianthus annuus)	59[2]	2260
29	Oleander (N. oleander), 300 ft-c	23	241	58	Taro (Colocasia antiquorum)	10	90,730
30	Orange (Citrus sinensis), 3 yr old	16,419	344,000	59	Wheat (Triticum aestivum), 600 ft-c	5	46-65
31	Orange (C. sinensis), 6 yr old	37,257	590,000				

/1/ Per stem. /2/ Calculated. /3/ Variety Crawford. /4/ Variety Elberta. /5/ Plants under artificial light, 600 ft-c. /6/ Plants, in experimental plots, spaced 2 ft x 2 ft. /7/ Plants spaced 4 ft x 4 ft.

This table is a summary of the salient topographic, ontogenetic, morphologic and functional characteristics of the most common types of cells in tical or experimental demonstration. Only approximate boundaries can be drawn between certain types of cells, and the occurrence of intergra- differentiation when appropriately stimulated. Spores, gametes and many specialized cells (e. g., endodermal cells, secretory cells of glands,

	Cell Type	Origin	Site
1	Apical meristem	Lineal descendents of cells of embryo except in adventitious shoots* and roots*.	Apices of vegetative shoots, developing inflorescences and flowers; in root beneath inner edge of root cap*.
2	Vascular cambial cells	From procambium* and from parenchyma in interfascicular areas, cortex*, and phloem*.	Lateral in stem and root, between secondary xylem* and secondary phloem*.
3	Phellogen (cork cambium)	In stems, first phellogen cells arise from cortex* (most commonly from outermost layer), or from epidermis or phloem* parenchyma cells; in roots from the pericycle*.	Lateral in stem and root, between phellem (cork) and subjacent phelloderm*, cortical or phloem* tissue; also beneath surface exposed by abscission of organs (e. g., leaf scars) or beneath wounds.
4	Epidermal cell	From the protoderm*.	The prevalent cell type in the surface layer (epidermis) of foliar and floral organs, young stems and roots.
5	Guard cells	Typically originate in pairs by the division of specific "mother cells" of the protoderm*. A pair of guard cells together with the intercellular space or pore between them is termed a stoma; in many plants, the paired guard cells are flanked or surrounded by distinctive subsidiary cells.	An extremely consistent cell type in the epidermis of foliage leaves and young stems; occurs also rather commonly in the epidermis of various types of floral organs; absent from the epidermis of roots.
6	Phellem (cork)	From phellogen; in stems of some monocotyledons tangentially dividing cortical parenchyma cells produce irregular bands of suberized cells termed storied cork.	Peripheral regions of stem, root and certain types of fruits; occurs in some bud scales and petioles; often produced as a result of wounding.
7	Parenchyma	From ground meristem*, procambium*, vascular cambium and phellogen.	Widely distributed throughout plant body; commonly the dominant cell type in cortex*, pith*, mesophyll*, fleshy fruits and the endosperm* of seeds; occurs in phloem* and xylem* as the component of vertical parenchyma strands and vascular rays*.
8	Collenchyma	From ground meristem*.	The sole component of cylinders or strands of tissue in the subepidermal portions of stems, petioles and the larger veins of leaves; may occur in cortex* of roots.
9	Sclereid	From protoderm* (e. g., in developing seed coats), ground meristem*, phellogen, vascular cambium and procambium*; frequently arises by sclerosis* of a fully developed parenchyma cell.	Common in seed coats and fruits; diffusely arranged in cortex*, functioning phloem*, outer bark, pith* and mesophyll* as idioblast* or as component of cell clusters; in leaves of some dicotyledonous genera restricted to vein endings (terminal sclereids).
10	Fiber	From protoderm*, ground meristem*, procambium* and vascular cambium.	Cortex*, primary and secondary vascular tissues of stem and root; epidermis of certain leaves; a component of the hypodermal strands or layers and the sclerenchymatous sheaths of vascular bundles* in many kinds of leaves; may occur as an idioblast*.
11	Tracheid	From procambium* and vascular cambium.	Primary and secondary xylem*; in a modified form, the distinctive cell type in the transfusion tissue* of gymnosperms* and commonly formed in masses in cultures of callus* tissue.
		tracheid-like cells occuring as idioblasts* or components of cell layers or groups in angiosperm leaves are termed "storage tracheids" by some dicotyledonous leaves;	
12	Vessel member	From procambium* and vascular cambium.	Primary and secondary xylem* of most dicotyledons; absent from xylem* of all gymnosperms except members of the Gnetales; in certain monocotyledons, restricted to the primary xylem* of the root.
13	Sieve cell	From procambium* and vascular cambium.	Primary and secondary phloem* of gymnosperms.
14	Sieve-tube member	From procambium* and vascular cambium.	Primary and secondary phloem* of angiosperms.
15	Laticifers	Non-articulated type from a single initial cell which develops into a continuous tube often ramifying throughout the plant; articulated type from an interconnected and progressively developed series of cells in which occurs a complete or partial resorption of certain cell walls.	Cortex*, phloem*, xylem rays*, pith*, mesophyll*.

GLOSSARY: ADVENTITIOUS SHOOT: A shoot arising from internodal regions of the stem, from roots, leaves, or from callus. ADVENTITIOUS wound-surfaces of stems, petioles, and roots. CORTEX: The zone of primary tissues situated between the epidermis and the vascular cylinder meristems or to different cell types. ENDOSPERM: Food-storing parenchymatous tissue in seeds, sometimes with massively-thickened cell dual cell which differs markedly in form, size, wall structure or contents from neighboring tissue-elements. LENTICEL: A small restricted MESOPHYLL: The photosynthetic parenchyma tissue of the leaf enclosed by the epidermis. PERICYCLE: The uniseriate or multiseriate zone suberized walls produced inwardly by the phellogen. PHLOEM: One of the tissues of the conductive or vascular system of the plant body; the cell, usually paired with a similar cavity in the adjacent cell; such pit-pairs are separated from each other by a common pit membrane, pressions in the primary walls of plant cells traversed by groups of protoplasmic strands or plasmodesmata; one or more pits may develop over primary vascular system (primary phloem and primary xylem) originates. PROSENCHYMATOUS: A term designating a cell which is conspicarises; in some cases, cells internal to the epidermis may also originate from the protoderm. ROOT CAP: A thimble-shaped or conical mass of because of the presence of thick, usually lignified cell walls. SCLEROSIS: The process whereby a parenchyma cell acquires a thick lignified sec- TISSUE: A tissue composed of relatively short, broad tracheids which flanks or surrounds the vascular bundles in gymnospermous leaves; in ening tissue composed primarily of phloem and xylem. VASCULAR RAY: A radial band or sheet of parenchyma cells produced by the division phloem is a phloem ray; the two are continuous. XYLEM: One of the tissues of the conductive or vascular system of the plant body; the definitive

seed plants. The typology adopted for the table reflects individual interpretation of morphologic data and hence is not subject to rigorous statisdations is indicated at several points in the table. Moreover, many types of living cells are capable of growth, division and further structural epithelial cells of resin ducts, cells of hairs) have not been included. Terms followed by an asterisk (*) are defined in the Glossary below.

Morphology	Functions	
Polyhedral; primary wall thin or irregularly thickened; primary pit fields* may be present; nucleus large, ovoid; cytoplasm vacuolated to varying degrees; mitochondria, plastid primordia and storage products may be present.	Point of origin of primary meristematic tissues, e.g., protoderm*, ground meristem* and procambium* from which primary body of shoot and root develops; in shoot apex, gives rise to the tissue of a leaf primordium.	1
Two types of cambial cells, viz.: elongate fusiform initials, from which tracheary elements, sieve elements, fibers and vertical parenchyma are derived, and ray initials, from which vascular rays* originate; cytoplasm of both kinds of initials highly vacuolated; primary walls with conspicuous pit fields.	Produce secondary phloem* and secondary xylem* cells. Growth in diameter of woody stems and roots results from tissue-formation by cambial cells.	2
Rectangular and radially flattened in transectional view, polygonal or nearly isodiametric in longisection; walls thin; cytoplasm vacuolated; may contain tannins and chloroplasts.	Produces phellem cells outwardly and in many cases, phelloderm cells* inwardly; forms complementary cells of lenticels*.	3
Polygonal, elongated or with undulate contour in surface view, variable in radial dimensions; walls thin or thick, the outer wall often the thickest; primary pit fields* present; walls typically cutinized (may be lignified or silicified), the outer wall covered by a cuticle except in roots; plastids, anthocyanin pigments and ergastic substances may occur.	Mechanical protection; restriction of transpiration; storage of H_2O and metabolic products; photosynthesis; H_2O absorption in roots; by division and dedifferentiation* may contribute to origin of adventitious shoots* and roots*.	4
Usually crescentic or kidney-shaped in surface view; walls unevenly thickened, cutinized and overlaid by a cuticle; often with ridge-like extensions above and below the pore; conspicuous starch-forming chloroplasts present; protoplast physiologically active in mature cells but rarely divides in response to wound or other stimuli.	Stomata are the important points of diffusion of gases through the epidermis. Reversible changes in turgor of guard cells result in the opening or closure of the pore.	5
Rectangular in transection and more or less radially flattened; irregular or rectangular in longisection; secondary wall typically suberized and occasionally lignified; pits absent; devoid of protoplasm at maturity; may contain resin and tannins.	Mechanical protection; restriction of transpiration.	6
Varies widely in shape from approximately tetrakisdecahedral to elongated or stellately branched; primary walls thin or thick, often with conspicuous pit fields; thick lignified secondary walls with pits* common in parenchyma cells of secondary xylem*; plastids and a wide range of ergastic substances present.	Photosynthesis; food and H_2O storage; secretion and excretion; commonly the protoplast retains marked capacity for growth, division and dedifferentiation* and hence prominently concerned in wound healing, formation of callus* tissue, and the origin of adventitious shoots* and roots*.	7
Relatively short and prismatic or elongated with tapering ends; primary walls unevenly thickened, composed of cellulose and pectin and with high percentage of H_2O; primary pit fields present; chloroplasts common; collenchyma and cortical parenchyma cells frequently intergrade in form and structure.	Mechanical support for growing stems and leaves; protoplast retains capacity for growth, division and dedifferentiation*.	8
Form extremely variable; polyhedral, prismatic, fusiform, filiform, irregularly lobed or profusely branched; in some cases intergrades in form with fibers; secondary wall thick and lignified (sometimes with embedded crystals); pits usually simple, often ramiform; protoplast may be retained at maturity.	Produces hard incompressible texture of many tissues.	9
Typical example of a prosenchymatous* cell, often reaching considerable length; secondary wall usually thick, often highly lignified; pits* abundant or sparse, simple or with greatly reduced borders; protoplast usually absent at maturity; a living protoplast and various ergastic materials occur in septate fibers; in secondary xylem* of dicotyledons, fibers and tracheids frequently intergrade in form and structure.	Mechanical support.	10
Typically elongated, with blunt, tapering or inclined ends; imperforate at maturity; secondary wall lignified, deposited in a wide variety of frequently intergrading patterns, i.e., as rings, one or several helical bands, layer interrupted only by bordered pits*; devoid of protoplast at maturity.	Conduction of H_2O and mineral solutes; mechanical support.	11
Elongated to drum-shaped, with inclined or transverse perforated end walls; developed as a component member of an extensive series of superposed cells termed collectively a vessel; perforations usually restricted to end walls and are either single (simple perforation plate) or multiple (scalariform, reticulate and foraminate types of perforation plates); secondary wall lignified, with same range of patterns as in tracheid; devoid of protoplast at maturity.	Conduction of H_2O and mineral solutes; and possibly mechanical support.	12
Elongate in form with overlapping inclined or tapering ends; sieve areas numerous, all similar and relatively unspecialized in structure; each sieve area is a portion of the primary wall traversed by connecting strands of cytoplasm enclosed by cylinders of callose; protoplast at maturity enucleate, devoid of stainable contents and starch; usually connected with modified parenchyma cells termed albuminous cells.	Conduction of organic solutes.	13
Elongated in form with inclined or transverse end walls; developed as a component member of a series of superposed cells termed collectively a sieve tube; end walls with highly specialized sieve areas termed sieve plates; sieve plates simple (one sieve area) or compound (many sieve areas); lateral walls usually bear less specialized sieve areas; protoplast at maturity enucleate and devoid of stainable contents and starch; usually connected with one or more nucleated parenchyma cells termed companion cells, the latter ontogenetically developed as sister cells of the sieve-tube member.	Conduction of organic solutes.	14
Contain latex and are multi-nucleate; primary walls often relatively thick in mature tubes; non-articulated type an unbranched or very often a profusely branched tube; vertical series of articulated laticifers may become joined by lateral anastomoses into a complex network.	Probably excretory because of storage of such apparently non-functional metabolic products as rubber and resin; role of laticifers as food conducting and food storing structures doubtful.	15

ROOTS: Roots arising from stems, leaves, or from callus. CALLUS: Tissue composed of parenchyma which originates by proliferation from in roots and stems. DEDIFFERENTIATION: The process by which living physiologically mature cells resume growth and division, giving rise to walls. GROUND MERISTEM: The undifferentiated tissue of a young organ exclusive of the protoderm and procambium. IDIOBLAST: An individual area of loosely-arranged cells situated in the periderm; the latter consists of the phellem (or cork), the phellogen, and the phelloderm. of parenchymatous tissue at the periphery of the primary vascular cylinder in roots. PHELLODERM CELLS: Parenchymatous cells with undefinitive conductive cell types in the phloem are the sieve cell and the sieve-tube member. PIT: A cavity or recess in the secondary wall of a PITH: A central column of tissue in the stem and in certain roots, bounded externally by the vascular cylinder. PRIMARY PIT FIELDS: Deeach pit field if a secondary wall is formed. PROCAMBIUM: Undifferentiated tissue composed of more or less elongated cells from which the ously elongated in form with tapering ends. PROTODERM: The undifferentiated surface cell layer of young organs from which the epidermis parenchymatous tissue occupying the true apex of the root. SCLERENCHYMATOUS: A term designating cells or tissues which are hard or tough ondary wall; may occur late in the functional life of the parenchyma element and sometimes coincides with a change in its form. TRANSPUSION Pinus, living parenchyma cells as well as tracheids occur in the transfusion tissue. VASCULAR BUNDLE: A strand of conducting and strengthof ray initials in the vascular cambium. That portion of a vascular ray found in the secondary xylem is a xylem ray; that portion in the secondary conductive cell types are the tracheid and vessel member. XYLEM RAY: See Vascular Ray.

Part I.

	Tissue	Cell Division in Postnatal Life	Mode of Postnatal Growth
1	Adrenal	Mitosis adult rat: zona capsula, 0.13%; zona glomerulosa, 0.17%; zona fasciculata, 0.13%; zona reticularis, 0.06%; total gland, 0.12%. Considerably higher figures in young rat.	Principally by cell division. Capsule may contribute.
2	Alimentary canal	Dividing cells in crypts of duodenum and ileum. In rat, make up 3% of all cells; cycle, 1.13 hr. In stomach, dividing cells at base of foveolae.	Cell division and differentiation in mucous membrane. Muscle, by combination of cell division and increase in cell size.
3	Blood erythrocytes	Confined largely to erythroblasts in bone marrow; dividing cells in man, 1.17-1.83%.	In precursors, growth phase sharply separated from phase of hemoglobin formation.
4	Blood granulocytes	Confined largely to myeloblasts (2.7%) and myelocytes (0.46%) in bone marrow.	Growth stages sharply demarcated from the stages of granule formation.
5	Blood lymphocytes	In tissues of origin. Dividing cells in 3 mo rat: thymus, 0.22%; lymph nodes, 0.058%; lymph follicles in spleen, 0.058%.	Derived from reticulum cells and may be converted to other forms, but this is disputed. In dog, 25 times 10^9/kg/hr enter circulation; in cat, 35 times 10^9.
6	Blood platelets	Division of circulating platelets not described.	Evidence favors formation in marrow from cytoplasmic fragmentation of megakaryocytes.
7	Brain and spinal cord	Very rare but has been recorded.	Growth of axones; myelination of fiber tracts; may not be completed until 18th yr in man.
8	Heart	Negligible in cardiac muscle.	Increase in size of muscle fibers. In rabbit, from birth to maturity, diameter of fibers increases times 2.6 (to 19μ); in man, times 2.6 (to 14μ).
9	Kidney	Rare after early postnatal life except for regeneration in rodents.	Increase in size of cells and structures. In man, from birth to maturity, diameter of glomerulus increases from 118-240μ; of proximal collecting tubules, from 18-34μ to 40-64μ. In rat, early postnatal growth partially caused by peripheral undifferentiated nephrogenic zone; number of nephrons doubled in first two weeks of postnatal life.
10	Liver	In rat, dividing cells rise from low values to 3.3% on 23rd da, then return to low values; mitotic percentage in adult albino rat, 0.005%.	In early life, considerable contribution from cell division; later, from increase in cell size.
11	Muscle, striped	Very scant and confined to nuclei. Some amitotic divisions.	Enlargement of fibers, possible splitting of fibers. In newborn, some continued formation from mesenchyme cells. Hypertrophy caused by increase of sarcoplasm in pre-existing cells.
12	Ovary	Mitosis demonstrated in germinal epithelium and, during early pregnancy, granulosa and theca interna cells.	In rabbit, follicles increase in size exponentially with time; completed in 18 da; total number of oocytes in gland related to age: log(number)=4.561-0.476 log(age in da).
13	Pancreas; submaxillary		Decrease of relative amount of connective tissue after birth; adult proportions reached at 11th-16th yr.
14	Parathyroid	Dividing cells in mice: 8 da, 0.07%; 18 da, 0.71%; 28 da, 0.1%.	Multiplication of clear or stem cells which differentiate into "dark" cells.
15	Prostate	In rat, mitosis numerous to 20th da; scant at 100 da.	In rat, by cell proliferation to 20th da, then by increase of cell size and diameter of acini. From 11-55 da height of cells increases from 18-34μ, and diameter acini from 43-170μ. Growth affected by hormonal activity. In man, some squamous metaplasia in newborn.
16	Skin	Occurs in varying proportions in stratum basalis and spinosum. In adult mice, 2-8 dividing cells/cm length of 7μ ear section; duration of mitotic cycle, 2.5 hr. Number of divisions varies with time of da, carbohydrate metabolism, hormonal stimuli, etc. In newborn mice, 2-4% of nucleated cells in mitosis. Mitotic percentage in the planta of the rat (250 g) averages 5.24% for 24 hr at 25°C.	Division of cells in deeper layers followed by differentiation.
17	Testis	In albino rat, cycle of spermatogonial division, 48 mm. Spermatogenic wave lasts 4 da; spermatogenic cycle takes 16 da.	
18	Thymus	Mitosis: adult rabbit, 0.52%; 3 mo rat, 0.22%.	Weight in man: birth, 12g; puberty, 40g; 60 yr, 15g.
19	Thyroid	100-125 dividing cells recorded in whole gland of guinea pig.	Following possibilities described: new follicles by budding; proliferation of undifferentiated interfollicular cells; proliferation of cells derived from follicles.
20	Uterus		Pregnancy: enlargement of pre-existing epithelial cells, glands and muscle fibers; cell division of epithelial and muscle elements in addition; new muscle fibers may form from indifferent cells. Menstruation: in proliferative phase mitosis in endometrium rises 0.56% and nuclei of muscle fibers increase in size; regression of secretory phase: denuded surface covered in 7 da by cells from remaining glands.

/1/ In peripheral nerves.

Part II: INCREMENTS OF WEIGHT

Each value is derived from the weight at the end of a time period

Tissue	Prenatal Period[1]			Birth to Adult	Tissue	Prenatal Period[1]			Birth to Adult
	8-12 wk	12-16 wk	20-24 wk			8-12 wk	12-16 wk	20-24 wk	
1 Brain	15	4.5	1.7	3.7	4 Liver	17	3.6	1.8	18
2 Heart	6.5	4.3	1.7	15	5 Muscle, striped				30-40
3 Kidney	75	6.7	1.6	10	6 Ovary				37

/1/ 280 da.

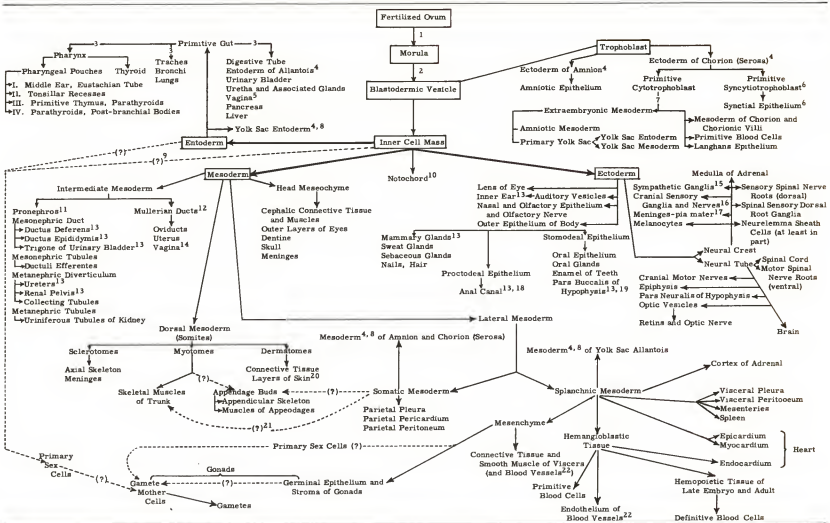
GENERAL

Life Span of Cells	Mechanism of Cell Replacement	Regenerative Capacity	
In cortex, uncertain but phagocytosis occurs in zona reticularis.	In cortex, cell division and migration of cells from superficial to deeper layers.	In cortex, after damage, repair by cell division but limited in adult. Active regeneration follows postnatal degeneration. Mitosis very scanty in medulla; postnatal growth from cell enlargement.	1
In small intestine, rat: 60-70% superficial epithelium shed/da; cell lives 1.57 da in duodenum, 1.35 da in ileum. Oral mucosa, rabbit, 5.1(4.5-5.7)/1000 cells [diurnal variation 3.8(3.6-4.0) and 7.2(6.6-7.8)]. Mitotic duration calculated as 64 min. Intermitotic period calculated as 208 hr.	Cells multiply in crypts in base of foveolae, move toward lumen and differentiate.	After removal of mucous membrane in dog's stomach, denuded area covered by growth of undifferentiated epithelium at rate of 2 mm/wk. Healing in 10 da if muscularis mucosae intact, 130 da if muscle destroyed. Brunner's glands can undergo limited regeneration. Cat's stomach: movement at 0.2-0.4 mm/hr; sudden loss of epithelium made good in a few hr.	2
120 da most generally accepted.	See Mode. In man, 0.83% red cells replaced each da.	In rabbit, recovery from 30% blood loss, 3 wk; in rat, 7 da. In man, recovery from loss of 600 ml, 50 da.	3
Neutrophils estimated at 7-80 hr; disappear from blood of cat at rate of 881/cu mm/hr.	Eosinophilia, 10-14 da.	Replaced 1.5 times/da in cat.	4
Approximately 24 hr. Removed from blood by lungs, spleen, lymph glands, skin, intestine.	See Mode. Replacement in blood stream about twice a day.	Limited regeneration of lymph nodes after removal in young rabbits; mesenchyme cells form complete gland in 3-4 wks.	5
In cat, 2-4 da; utilization at rate of 2500/cu mm blood/hr.	After loss, new formation begins in a few hr. Normal regained 3-4 da.		6
Coextensive with normal function.	Confined to neuroglia.	Very largely confined to neuroglia; some axone formation. Regeneration of motor axones occurs at 4 mm/da after latent period of 7a da. A large number of factors affect rate. Preganglionic fibers[1] of cat regenerate in 36-61 da; function restored in 44 da.	7
Coextensive with normal function.	None.	Negligible. Hypertrophy caused by increase in size of fibers. Rabbit: normal diameter, 19.2μ; hypertrophied, 22.2μ; man, normal, 14μ; hypertrophied, 25μ.	8
Very largely coextensive with normal function.	By cell division in tubules.	True regeneration observed in rats. Hypertrophy caused by enlargement of existing elements, but increased cell division has been demonstrated after unilateral nephrectomy in the rat.	9
No figure quotable.	Dividing cells persist in small numbers in adult presumably to replace cell loss, smaller extent in duct cells. Division also occurs in Kupffer cells and connective tissue cells.	In rat, extirpation of 2/3 regenerated in 21 da, caused by cell division in the parenchymal cells, and to a	10
Coextensive with normal function.	Normally none.	Protoplasmic outgrowth from pre-existing fibers in which nuclei may divide by amitosis. Outgrowth begins 3rd da after injury, progresses at 1 - 1.5 mm/da. New fibers 30% normal diameter in 21 da; normal diameter in 4 mo. No new formation from indifferent cells.	11
Fertility of shed ova lost: rabbit, 12 hr; guinea pig, 26 hr; ferret, 30 hr.		No regeneration of ova but marked regeneration activity of germinal epithelium after hormonal stimulation.	12
		Limited amount after resection or duct ligation. Mitosis in acinar cells and duct epithelium, the latter giving rise to acinar cells and islet cells. In rat, submaxillary gland regeneration by division of acinar cells in 1st week, followed by proliferation of ducts with acini formed with terminal portions.	13
		Negligible. Hypertrophy and hyperplasia in chronic nephritis.	14
	Regeneration after surgical removal very rare in man.		15
Variable and dependent on rate of shedding of keratinized cells. Plantar epidermis cells of rat 19.1 da, of which 16.9 da are spent in basal layer and 2.2 da in stratum granulosum. Mitotic index: in corneal epithelium, rat (80-150g), 0.4%, arm, 1.5; face, 2.1-3.5.	See Mode. Adjustment between cell loss and cell formation.	Re-epithelization of wounds by proliferation and migration of adjacent cells. Regeneration possible from hair follicles. Rate of healing greater in larger wounds. Growth of granulation tissue checked by epithelial overgrowth. Nails (man): growth 95μ/da (thumb). Fingernail growth 4 times toenail. Hair length of cycle depends on thickness. Man: head, 3 yr; eyebrow, 120 da. Body of rat, 35 da. Rate of growth (man) varies with site (mm/wk): head, 2.7; Replacement by multiplication and differentiation of cells at bottom of hair follicles.	16
Sperm survival times in man, 48-72 hr; horse, 12 hr; mouse, 13.5 hr; rabbit, 96 hr; some bats may overwinter.		Possible after slight injury. In rabbit, 1 da in abdominal cavity causes loss of spermatogenic elements, with restoration in 2 wk.	17
			18
		After partial removal, hypertrophy of remainder preventable by iodine administration.	19
	Experimental incision in mouse heals in 48 hr without scar. Smooth muscle fibers retain some power of division; new formation possible from undifferentiated connective tissue cells. Regeneration (smooth muscle) after injury limited, and fibrous scar usual.		20

INCREASE: MAN

divided by the weight at the beginning of the same time period.

	Tissue	Prenatal Period[1] 8-12 wk	Prenatal Period[1] 12-16 wk	Prenatal Period[1] 20-24 wk	Birth to Adult		Tissue	Prenatal Period[1] 8-12 wk	Prenatal Period[1] 12-16 wk	Prenatal Period[1] 20-24 wk	Birth to Adult
7	Pancreas	Av 16	Av 16	1.6	20-40	10	Thymus	400	3.7	1.9	
8	Pituitary	2.5	3	1.7	3-6	11	Thyroid		6.6	2.2	14
9	Adrenal cortex	25	5	1.7		12	Uterus				27



/1/ By cleavage divisions. /2/ By hollowing out and expansion. /3/ Epithelial portion of the structure from entoderm, remainder from mesoderm. /4/ Extraembryonic, i.e., part of the placenta or other extraembryonic membranes. /5/ Lower part. /6/ Variable, not present in all mammals. /7/ In primates only. /8/ Probably not in primates. /9/ In man. /10/ Embryonic structure. May form nucleus pulposus of intervertebral discs. /11/ Embryonic structure; disappears. /12/ Or from splanchnic mesoderm of peritoneum. /13/ Epithelial portion of the structure from ectoderm remainder from mesoderm. /14/ Upper part. /15/ Absolute derivation of neural crest on disputed grounds. /16/ Evidence from lower vertebrates that a portion of these may be derived from ectodermal placodes. /17/ Probably only part of pia mater, not dura or arachnoid. /18/ In part only. /19/ Anterior lobe and pars intermedia of the pituitary. /20/ In region of somites only. /21/ Ventral and lateral part, evidence from chick only. /22/ Not all from splanchnic mesoderm; some from somatic mesoderm or head mesenchyme.

This table gives no clue to the combination of activities constituting a single response, except that activities reported as observed at the same gestation age may, in some instances, form a response pattern. Unless otherwise indicated (as "spontaneous"),each response is to be considered an induced exteroceptive reflex.

	Motor Activity	Gestation Period, %[1]				
		Man[2]	Cat[3]	Guinea Pig[4]	Rat[5]	Sheep[6]
1	Earliest spontaneous[7] activity[8]	22.5	36	40		22. 3
2	Earliest proprioceptive activity[8]	18.7-23.8				21. 6-28[9]
3	Appearance of earliest and latest exteroceptive reflexes[10]	18.7-80	26-74	38-76	75-90	26-57[11]
	Head					
4	Extension	26	42	48	76-79	26
5	Lateral flexion at neck	18.7	37-38	48	76	23-29[12]
6	Ventral flexion	32	36-42	52		35
7	Rotation	28	36-42	51	76	24. 8-26[12]
	Face					
8	Forehead movements	28		60		
9	Palpebral muscle movements	28		54		
10	Eyes, movement globus oculi	31		58		32[7]
11	Oronasal muscle movements	31	39	58	90	32
12	Lip movements	31		54		
13	Mouth closing	31		54	90	26
14	Mouth opening	23.8		52	77	26-32[12]
15	Mouth pursing	55				
16	Tongue movements	35	44-56	55	77	
17	Sucking	72[13]	74	55		31
18	Swallowing	30				51
19	Phonation	59[13]	74			
	Neck					
20	Extension	26		39		24. 2-35[12]
21	Lateral flexion	18.7		39	76	29
22	Ventral flexion			38		26
	Trunk					
23	Rotation or twisting	35	39-41	54	81	
24	Chest contractions, respiratory	30-32	50			24. 2-31[14]
25	Diaphragmatic contractions, resp	55	67			24. 2[7]
26	Effective respiration	59[13]				
27	Abdominal muscle contractions	38	42-50	46-58[15]	81	
28	Cremasteric reflex	80		76		50
29	Tail movements		42-47		86	
	Upper trunk[15]					
30	Extension	26	42	45		
31	Lateral flexion	20	36-39	40-46[7]	75-76[16]	23-26[12]
32	Ventral flexion		38	43	77	24. 2[7]
33	Lower trunk[15]					
	Extension	26	42	45	76	
34	Lateral flexion	21.2	39	40-46[7]	75	
35	Ventral flexion		38	43	77	24. 2[7]

	Motor Activity	Gestation Period, %[1]				
		Man[2]	Cat[3]	Guinea Pig[4]	Rat[5]	Sheep[6]
	Rump					
36	Extension	26	52	55	81	
37	Lateral flexion		41	49	76	
38	Ventral flexion		39-48[17]		77	
39	Rotation	21.2	47		81	
	Upper extremity					
40	Movement with trunk	21.2	37		76	
41	Adduction at shoulder		50	48		
42	Abduction at shoulder	29	33			23-26[12]
43	Extension at shoulder	21.2	39	39	75[16]	26
44	Flexion at shoulder		35-39	39		26
45	Rotation, medial	28				
46	Elbow extension	30	38			24. 8[7]
47	Elbow flexion	28	39	48	81	24. 8-28[12]
48	Forearm pronation	28				
49	Wrist extension		58[16]		86	
50	Wrist flexion	28	38-48	48	75-81[17]	
51	Pollex flexion	26				
52	Pollex opposition	32				
53	Finger flexion	26		54		
54	Finger closure, maintained	38				
55	Grasp	46				
	Lower extremity					
56	Movement with trunk				77	
57	Scratch reflex			54		57
58	Adduction at hip			67		
59	Abduction at hip		38-45[17]			
60	Extension at hip	29	24. 2-47[12]	51	81	
61	Flexion at hip	28	42-45	48	86	26
62	Rotation, lateral	28				
63	Rotation, medial	28				
64	Knee extension	32				24. 8[7]
65	Knee flexion	29	44-58[17]			24. 8[7]
66	Ankle adduction		68[16]			
67	Ankle dorsiflexion	29				24. 8[7]
68	Ankle plantar flexion		61			24. 8[7]
69	Ankle rotation		68[16]			
70	Hallux dorsiflexion	34				
71	Hallux plantar flexion	28				
72	Toe fanning	34				
73	Toe dorsiflexion	34	73[16]			
74	Toe plantar flexion	28	73[16]			

/1/ Per cent of gestation period = per cent of total gestation period elapsed at the time the motor activity appears. The gestation period is measured from the time of insemination except for man, in which case measurement is from the first day of the last menstrual period. To convert, in the case of man, to per cent of gestation period on insemination age, the following equation may be employed:

Corrected per cent = $\frac{(\text{given per cent} \times 40) - 200}{38}$

/2/ Gestation period = 280 da measured from the beginning of last menstrual period; corrected = 266 da from ovulation. /3/ Gestation period = 66 da (see Fn 1). /4/ Gestation period = 67 da (see Fn 1). /5/ Gestation period = 21 da (see Fn 1). /6/ Gestation period = 157 da (see Fn 1). /7/ Spontaneous activity; believed to be essentially reflex in mammals. /8/ Unspecified. /9/ Doubtful reflex at the lower limit of this range. /10/ Complex patterns of behavior; behavior released by the head exteroceptors not included. /11/ Doubtful reflex at 22. 3% of gestation period. /12/ See Fn 7; the qualification applies only to the lower limit of this range. /13/ Human fetus viable at 68% of gestation period (27 wk). /14/ Spontaneous activity at 26% of gestation period. /15/ Data for guinea pig do not distinguish between movements of the upper and lower segments of the trunk. /16/ Movement is reported without specific data as to direction of movement. /17/ See Fn 16; the qualification applies only to the lower limit of this range.

Time of origin is expressed in three ways, depending on available information: (1) days or hours of incubation, (2) number of pairs of somites, or (3) normal "stages" as described by Hamburger, V., and Hamilton, H. L., J. Morphology 88:49, 1951. Data adapted from Lillie's "Development of the Chick," Henry Holt & Co., 1952. Footnotes refer to onset of function only.

	Organ or Structure	Time of Origin	Site of Origin
1	Abducens nerve	3rd da	Floor of myelencephalon beneath nerve VII.
2	Acrochordal cartilage	4½ da	At anterior tip of notochord.
3	Acoustico-facialis ganglion		Anterior edge of auditory pit.
4	Facial component	By stage of 15 s	From neural crest and posterodorsal epibranchial placode of 1st visceral furrow.
5	Acoustic component	21 s	From wall of auditory vesicle.
	Adrenal gland		
6	Cortical component [1]	78 hr	Coelomic epithelium at level of somites 17-22.
7	Medullary component [1]	4-7 da	From migratory cells of neural crest and sympathetic ganglia.
	Air sacs of lung [2]		
8	Primary bronchi and mesobronchi	4 da	Posterior end of trachea.
9	Entobronchi (secondary bronchi)	6th da	Mesial wall of anterior part of mesobronchus.
10	Ectobronchi (secondary bronchi)	6th da	Dorsal surface of middle part of mesobronchus.
11	Parabronchi (tertiary bronchi)	8-11 da	From secondary bronchi.
12	Allantois	28 s	Floor of hindgut just anterior to anal plate.
	Amnion (and Chorion) [3]		
13	Anterior amniotic fold	8-9 s	Anterior edge of proamnion (in front of head).
14	Posterior amniotic fold	27 s	From somatopleure posterior to tail.
15	Aorta, dorsal [4]	5 s	From hemangioblasts at ventrolateral margin of somites.
16	Aorta, ventral	3-5 s	From hemangioblasts continuous anteriorly with primordia of heart.
17	Aortic arch 1 [4]	9-10 s	Anterior to hyomandibular cleft.
18	Aortic arch 2	19-24 s	Posterior to hyomandibular cleft.
19	Aortic arch 3	26 s	Between visceral clefts 2 and 3.
20	Aortic arch 4 [5]	36 s	Between visceral clefts 3 and 4.
21	Aortic arch 5 [5]	4th da	Just anterior to aortic arch 6 and attached to the base and summit of arch 6.
22	Aortic arch 6	4th da	Behind 4th visceral cleft.
23	Auditory ossicles	5-6 da	From mesoderm above dorsal extremity of tubotympanic cavity.
24	Basiocciptal bone	After 13 da	Skull.
25	Beak	5 da (Stage 27)	
	Blood cells		
26	Granulocytes	3 da	
27	Neutrophils	5 da	
28	Eosinophils	7 da	Spleen (?).
29	Basophils	14 da	Spleen (?).
30	Lymphocytes	17 da	Spleen and other lymphatic areas.
31	Macrophages	12 s	From endothelium or mesenchyme.
32	Thrombocytes	3-4 da	
33	Bursa of Fabricius [6]	5-6 da	Posterodorsal wall of cloaca.
34	Cecal processes	7th da	Junction of small and large intestine.
35	Canal of Schlemm	8th da	Margin of anterior chamber of eye.
36	Cardinal vein, anterior	12 s	From intersegmental capillary sprouts of the dorsal aorta.
37	Cerebellar fissures	10-11 da	External surface of cerebellum.
	Chorion (see Amnion)		
	Chromaffin cells (see Adrenal, medullary component)		
38	Ciliary processes [7]	8th da	From ciliary region of lenticular zone of optic cup.
	Circulation of blood		
39	Clavicle ossification	8-9 da	

	Organ or Structure	Time of Origin	Site of Origin
78	Hindgut	21 s	In splanchnopleure, with appearance of tail fold.
79	Hypoglossus (Cranial nerve XII)	78 hr	From ventral part of neural tube opposite somites 3-4.
80	Hypothalamus	97 hr	Ventral wall of diencephalon.
81	Interatrial septum	50-55 hr	From vault of atrium between openings of sinus venosus and pulmonary vein.
82	Interstitial cells	13th da	In stroma of testis.
83	Interventricular septum	4th da	Along sulcus from bulbo-atrial angle towards apex of heart.
84	Islets of Langerhans [11]	8-9 da	Within pancreatic diverticula.
85	Jaw, upper	4-5 da	Fusion of fronto-nasal and maxillary processes.
86	Jugal bone	9th da	Skull.
87	Jugular lymph sac	7 da	Fusion of lymphatic vessels near anterior cardinal vein.
88	Labial groove	Stage 36 (10 da)	In periderm of tip of jaws.
89	Laryngotracheal groove	23 s	Postbranchial floor of pharynx.
90	Leg bud	50-60 hr (Stages 16-17)	Somatopleure lateral to posterior-most somites and segmental plate.
91	Lens invagination	20-21 s	Ectoderm overlying optic vesicle.
92	Lingual glands	11 da	From oral epithelium beneath lateral margin of tongue.
93	Liver [12]	22 s	Diverticula of the entoderm of the anterior intestinal portal.
94	Lungs [2]	23 s	Postbranchial floor of pharynx.
95	Mandible, ossification	9th da	
96	Mandibular glands	8th da	Solid ingrowths of mucosa from base of tongue forward to near mandibular symphysis.
97	Mantle layer of spinal cord	3rd da	From middle zone of neural tube.
98	Maxilla (bone)	9th da	
99	Mesenteric vein	5th da	In dorsal mesentery, near level of dorsal pancreas.
100	Mesenteries, accessory	60 hr	Mesenchymatous outgrowths of splanchnic mesodermal covering of lateral wall of esophagus.
101	Mesocardia, lateral	10 s	At point of contact of somatopleure with proximal part of vitelline veins.
102	Mesonephric tubules [13]	29-30 s	From nephrotome between somites 13-14 and 30.
103	Mesothalamus	97 hr	Lateral wall of diencephalon.
104	Metanephric tubules [14]	7-8 da	Metanephrogenous blastema just behind level of umbilical arteries.
105	Nares, external and internal	4-5 da	By fusion of median and lateral frontonasal processes with-maxillary processes of visceral arch 1.
106	Nasal bone	9th da	
107	Nasal (olfactory) pits	Stage 17	Ectoderm of ventrolateral sides of head opposite telencephalon.
108	Neostriatum	8-12 da	Telencephalic cortex.
109	Neural crest	6-7 s	In head.
110	Neural folds	Stages 6-7	Anterior end of medullary plate.
111	Neural tube	Stage 8	Level of future mid-brain.
112	Neuroblasts, retinal	4th da	Fundus of retina.
113	Nictitating membrane	7th da	From semilunar fold of integument within eyelid on side next to beak.
	Notochord (see Head-process)		
114	Oculomotor nerve	28-30 s	Ventral zone of mid-brain, near median line.
115	Olfactory epithelium	28 s	Ectoderm of head, in front of eyes.
116	Olfactory nerve	4-6 da	Olfactory epithelium.
117	Oocytes	Shortly after hatching	Ovarian cortex.

40	Claws	10 da (Stage 36)		118	Oogonia	7-8 da	From germ cells in secondary sexual cords of ovarian cortex.
41	Coelom	1-3 s	Within lateral plate mesoderm.	119	Optic vesicles	Stages 8-9	From lateral wall of fore-brain.
42	Comb	10 da (Stage 36)	Dorsal midline of beak.	120	Oral plate, rupture	30 s	
				121	Ostium tubae abdominale	5th da	Anterior end of tubal ridge (primordium of oviduct).
43	Conjunctival sac	7th da	Within folds of eyelids.	122	Otocyst	12 s	Thickened ectoderm on dorsal surface of head opposite posterior-most neuromeres of hind-brain.
44	Coracoid, chondrification	End of 6th da	Near union of coracoid with scapula.				
				123	Otocyst closure	28-30 s	
45	Cornea propria	4th da	Beneath the cornea epithelium.	124	Ovary, cortex	9-11 da	Proliferation from germinal epithelium.
46	Cornea, inner epithelium (Bowman's membrane)	100th hr	From mesenchyme on inner face of cornea propria.	125	Oviduct	4th da	Thickened peritoneum on dorsolateral surface of anterior end of mesonephros.
47	Cornea, Descemet's membrane	13-15 da	Beneath Bowman's membrane.	126	Oviduct, junction with cloaca	7th da	
48	Costal processes (ribs)	5th da		127	Palatine glands	After 11th da	From oral epithelium near choanae.
49	Crop	6th da	Dilation of esophagus at base of neck.				
50	Cushions, endocardial, of atrioventricular canal	3-4 da	Floor and roof of the atrioventricular canal.	128	Pancreas[15], dorsal diverticulum	35 s	Dorsal wall of intestine, immediately above posterior liver bud.
				129	Pancreas[15], ventral diverticulum	4 da	From common hepatic diverticulum near its junction with duodenum.
51	Dermis differentiation of fibers	Stage 38 (12 da)	Within mesenchyme next to ectoderm.	130	Paraphysis	4½ da	Roof of telencephalon, just in front of the velum transversum.
52	Diencephalon delimitation	18-20 s	From primitive fore-brain.				
53	Duct of Cuvier (common cardinal vein)	15 s	From capillary plexus between root of anterior cardinal vein and omphalomesenteric vein at level of somite 4.	131	Parasphenoid bone	12th da	Skull.
				132	Parathyroid	6-8 da	Ventral portion of visceral pouches 3 and 4.
54	Ductus choledochus	68 hr	From depression of ventral wall of duodenum.	133	Parencephalon	18-20 s	Anterior portion of diencephalon.
55	Egg-tooth[2]	Stage 30 (6½-7 da)	Dorsal tip of beak.	134	Parietal bone	13th da	Skull, behind squamosal bone.
				135	Patella	13th da	Anterior face of knee joint.
56	Embryonic shield	Stage 1	Posterior half of blastoderm.	136	Pecten	5th da	Growth of lips of optic cup over mesodermal keel of choroid fissure.
57	Epimyocardium[8]	3-5 s	From thickening of splanchnopleure of amnio-cardiac vesicles.	137	Pelvic lymph sac	5 da	Hemangioblasts from intersegmental veins of pelvic region.
58	Epiphysis	Stage 17 (30-35 s)	Roof of diencephalon.	138	Perilymph of ear	6th da	Mesenchyme surrounding otocyst.
59	Epithalamus	97 hr	Dorsolateral wall of diencephalon.	139	Pharynx (foregut)	Stage 6	From entoderm of head fold.
60	Esophagus	About 36 s	Gut immediately behind pharynx.	140	Pigment of choroidea of eye	End of 7th da	From neural crest cells which invade at early stage.
61	Exagius, gland[9]	16 da	From entodermal epithelial lining of esophagus.				
62	Eye pigment	Stage 20		141	Pigment of retina	Middle of 4th da	In situ in outer wall of retina.
63	Eyelids	7th da	Circular fold of integument around the eyeball.				
64	Facial nerve	3-4 da	From anteroventral portion of acoustico-facialis complex.		Pleuroperitoneal septum	(see Mesenteries, accessory)	
				142	Preganglionic column (visceral motor nucleus)	4½-8 da	From neuroblasts of ventrolateral motor column, which migrate to dorsolateral angle of central canal, spinal cord.
65	Femur, ossification	8th da					
66	Funiculi procervicales	6th da	From ectoderm connecting 3rd and 4th visceral pouches with cervical sinus.	143	Premandibular head cavities	23 s	Within prechordal mesoderm.
67	Gallbladder	68 hr	Hindmost part of posterior liver bud.				
68	Germ wall	During cleavage (prior to laying)	From marginal peribast.	144	Premaxilla (bone)	End of 9th da	Skull.
				145	Primitive streak	Stage 2	Posterior edge of pellucid area.
				146	Pyramidal glands	5th da	Evaginations of entoderm of stomach.
69	Germinal epithelium (primordium of gonad)	38 s	Coelomic epithelium at level of somites 20-27.	147	Pterygoid bone	End of 9th da	Skull.
70	Gizzard	5th da	Posterior part of stomach.	148	Pulmonary artery	35 s	From network of hemangioblasts extending caudally from ventral aorta.
71	Gizzard glands[10]	13-14 da	Lining epithelium of gizzard.				
72	Glossopharyngeal ganglion	17 s	From neural crest and epibranchial placode of 2nd visceral furrow.	149	Pulmonary diaphragm, muscles	10th da	
73	Glycogenic body of spinal cord	7½ da	Roof plate of spinal cord at level of spinal nerves 26-29.	150	Pulmonary vein	20 s	From proliferation of hemangioblasts from dorsal wall of sinus venosus at level of lung buds.
74	Harderian gland	8th da	From conjunctival sac at innermost angle of nictitating membrane.	151	Quadrate bone, otic process	End of 9th da	Skull.
75	Head fold	Stage 6	At anterior end of medullary plate.	152	Quadratojugal bone	End of 9th da	Skull.
76	Head-process (notochord)	Stage 5	Anterior edge of Hensen's node.				
	Heart (see Epimyocardium)			153	Rathke's pouch[16]	20 s	From ectoderm of roof of stomodeum, immediately anterior to oral plate.
77	Hepatic portal vein, definitive vessel	5th da	From the mesenteric vein in the dorsal mesentery.	154	Renal portal system[17]		Through substance of mesonephros.

/1/ 8th da (180 hr). /2/ 19-21 da (time of hatching). /3/ From time of fusion of component folds, shortly after stage of 31 somites. /4/ With beginning of circulation at stage of 16 somites. /5/ Vesigial. /6/ Shortly prior to hatching. /7/ Stage of 16 somites. /8/ Contractions begin at stage of 9 somites. /9/ 19 da. /10/ 17½ da. /11/ 11-12 da. /12/ 7th da. /13/ Beginning of 4th da. /14/ 11th da. /15/ Islets, 11-12 da; acini, after hatching. /16/ Cellular types differentiate during 10th da. /17/ 5th da.

127. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: CHICK (Concluded)

Time of origin is expressed in three ways, depending on available information: (1) days or hours of incubation, (2) number of pairs of somites, or (3) normal "stages" as described by Hamburger, V., and Hamilton, H. L., J. Morphology, 88:49, 1951. Data adapted from Lillie's "Development of the Chick," Henry Holt & Co., 1952. Footnotes refer to onset of function only.

	Organ or Structure	Time of Origin	Site of Origin
155	Rete cords of gonad	5th da	In stroma between genital primordium and mesonephros.
156	Sacculus	6-7 da	Protuberance on median surface of uppermost part of the pars inferior of the otocyst.
157	Scales of leg	Stage 37 (11 da)	Anterior surfaces of lower leg and toes.
158	Scapula	4-5 da	Base of wing bud.
159	Scleral papillae of eye	Stage 30 (7th da)	On conjunctiva surrounding iris, at some distance peripheral to its margin.
160	Sclerotic cartilage	8 da	In sclerotic (outer) coat of eye.
161	Semicircular canals of inner ear	5th da onward to 12th da	From pars superior of otocyst.
162	Septal gland of nose	8th da	Solid cord of cells from inner wall of vestibulum, opposite base of the vestibular turbinal.
163	Septum aortico-pulmonale	5th-6th da	Within truncus and bulbus arteriosus.
164	Shell of egg	4½-24 hr after ovulation	Uterus.
165	Shell membrane of egg	3½-4½ hr after ovulation	Isthmus of oviduct.
166	Spermatogonia	13th da onward	From primordial germ cells within sexual cords of testis.
167	Spinal nerves, motor component	3rd da	From medullary neuroblasts of ventral horn, spinal cord.
168	Spleen	2nd half, 4th da	Proliferation of peritoneum of left side of dorsal mesentery, just above the dorsal pancress.
169	Spur	Stage 36	Medial surface of leg, just proximal to base of first toe.
170	Squamosal bone	End of 9th da	Skull.
171	Stapes	7-8 da	From mesenchyme adjacent to the bottom of the external auditory meatus.
172	Stomodeum	12 s	From expansion of embryonic parts surrounding the oral plate.
173	Subcardinal vein	70 hr	From series of venous islands on median surface of mesonephros.
174	Subclavian artery	4th da	From the segmental artery of the 18th intersomitic space.
175	Subintestinal vein	3rd da	From a plexus of capillaries around the gut.
176	Sympathetic nervous system	End of 3rd or beginning of 4th da	Aggregation of neural crest cells at dorso-lateral angle of dorsal aorta.
177	Synencephalon	18-20 s	Hindmost third of the diencephalon.
178	Tail bud	20-21 s	From primitive knot and remnant of primitive streak conolidated with it.
179	Teeth (vestige of dental ridge)[5]	6 da	Thickened ridge of ectoderm just inside margin of jaw.
180	Thoracic duct of lymphatic system	6-7 da	From intramesenchymal spaces along ventro-lateral side of dorsal aorta.
181	Thymus	6-8 da	From dorsal part of visceral pouches 3, 4, and possibly 5.
182	Thyroid[18]	12 s	Thickened epithelium of median floor of pharynx between levels of visceral arches II and III.
183	Toe	Stage 25	Toe plate of leg bud.
184	Trachea	4 da	Hinder portion of laryngotracheal groove.
185	Trigeminus, neural crest component	13-14 s	Neural crest of level of mstencephalon.
186	Trigeminus, component from epibranchial placode	25-27 s	From ectodermal placode in front of and above first visceral cleft.
187	Trochlear nerve	End of 3rd da	Dorsal surface of brain in region of isthmus.
188	Trunk flexure	Stage 14	Behind level of somites 7-9.
189	Tuberculum impar of tongue	4th da	Slight rounded swelling between lower ends of first and second visceral arches.
190	Turbinals, nasal	4-8 da	From folds of lateral wall of nasal cavity.
191	Middle[19]	Beginning of 5th da	From ventral part of lateral nasal wall.
192	Superior	5-6 da	Immediately above the middle turbinal.
193	Vestibular[19]	6-8 da	
194	Umbilical vein	3-4 da	From capillary plexus in the somatopleure extending back from duct of Cuvier.
195	Uncinate processes	Da before hatching[20]	Membranous ossifications along sternal ends of ribs (?).
196	Ureter[14]	End of 4th da	Broad diverticulum of mesonephric duct at the convexity of its terminal bend to the cloaca.
197	Uropygial gland[21]	10th da	From a pair of ectodermal invaginations at the dorsal midline of the base of the uropygium.
198	Uterus (shell-gland)[21]	12th da	Posterior end of left oviduct.
199	Vagus nerve, neural crest component	20 s	Indistinct aggregation of neural crest immediately in front of level of duct of Cuvier.
200	Vascular system	3-5 s and onward in later stages	Initiated in blood islands at posterior margin of area opaca.
201	Velum transversum	18-20 s	Indentation in roof of fore-brain.
202	Vertebrae, chondrification	7-8 da	Within membranous parts of vertebrae.
203	Vertebral artery	6-7 da	From the first 5 or 6 segmental arteries, and the plexus they form around the secondary sympathetic ganglia.
204	Visceral cleft 1	26 s	In pharyngeal region.
205	Visceral cleft 2	35 s	In pharyngeal region.
206	Visceral cleft 3	40 s	In pharyngeal region.
207	Visceral pouch 4, contact with ectoderm	35 s	Branchial region. No cleft develops.
208	Wattles	Stage 37	Throat.
209	Wing bud	50-60 hr (Stage 16)	Somatopleure lateral to somites 14-20.
210	Wing feathers	7 1/4 da	Along outer margin of wing.

/5/ Vestigial. /14/ 11th da. /18/ 10th da. /19/ Non-sensory. /20/ Calcification starts at least one day prior to hatching. /21/ After hatching.

	Organ, Tissue or Characterization	Stage of Appearance	Embryo Size[1] mm	Age da[2]
1	One cell	1	0.11-0.14	
2	Two cells	2		25-41 hr
3	Four cells	3		2.5 hr
4	Eight to twelve cells	4		3
5	Sixteen cells (morula)	5		3.5
6	Blastocyst	6		4.75
7	Late blastocyst (still free in uterus)	7		5-7
8	Bilaminar disc (beginning elongation)	8	0.49-1.36[3]	7-8
9	Proliferation of mesoderm	9	2.5-3.03	8-9
10	Primitive streak beginning	10		8-9
11	Medium primitive streak	11		10
12	Completed primitive streak; notochord	12	10-65[3]	11-12
13	Presomite neurula; neural plate and groove; hindgut	13		13
14	Pericardial cavity; endocardium; epimyocardium; anlagen of blood vessels; foregut; preoral gut; oral plate; allantois; occipital somites 1-4[4]	14	2.5-3.0	14-15
15	Cervical somites 5-12; visceral pouches 1-2; pharynx; mesonephros; neural tube; fusion of neural crest primordia; auditory placode; optic vesicle; fusion of paired cardiac tubes; blood in yolk sac, heart and vessels; ventral aorta	15	3.2-5.2	15-16
16	Thoracic somites 13-20; spiral torsion; truncus and bulbus arteriosus; ventricle; atrium; sinus venosus; glomeruli in mesonephros; dorsal aortae; first pair aortic arches; 3rd and 4th visceral pouches; liver diverticula; prosencephalon; mesencephalon; rhombencephalon; auditory pit	16	4.0-6.5	15-17
17	Thoracic somites 21-24; telencephalon; diencephalon; metencephalon; myelencephalon; closure of anterior neuropore; longitudinal neural artery; lateral cardinal vein	17	4.9-6.5	17
18	Thoracic somites 25-26; head and tail meet; anterior limb bud; 2nd aortic arch; endocardial cushions; esophagus; stomach; post-cloacal gut; proctodaeum; anal plate; intestine; auditory vesicle; thyroid; hypophysis	18	3.8-4.5[5]	16.5-18
19	Lumbar somites 27-29; hind limb bud; pancreas; lung buds; 3rd aortic arch; Gasserian and acoustico-facialis ganglia; interventricular septum	19	3.6-4.6	16.5-17.5
20	Lumbar somites 30-31; spiraling completed; 4th aortic arch; mesial cardinal vein; venous valves; oral plate ruptures; gallbladder; trachea	20	4.5-7.0	17.5
21	Lumbar somites 32-33; uncoiling; mandibular and maxillary processes; elongation of nuclei of mesenzyme cells in region of circular muscle layer of esophagus at level of laryngotracheal groove	21	5.0-5.2	17.5
22	Sacral somites 34-35; cranial ganglia IX and X; crsnial nerves 3-12; optic cup and lens; 6th aortic arch; epiglottis; notochordal sheath; tongue primordia	22	5.8-8.0	19
23	Sacral somites 36-37; metanephric duct; foramen II in septum I	23	6.4	20
24	Caudal somites 38-40	24		20
25	Caudal somites 41-43; olfactory pits; lateral and median nasal processes; septum II; external carotid; adrenal cortex; myoblasts elongate; dermomyotome differentiates	25	8.0-8.6	20
26	Caudal somites 44-46; beginning umbilical hernia; pelvis; bronchi branching; myofibrillae in myoblasts of esophagus; ependymal mantle and marginal layers of neural tube; neuroblasts; retinal differentiation; cerebral hemispheres; saccules; utriculus; bulbus dividing into aortic and pulmonary trunks; inferior vena cava; spleen; anlagen of external genitalia	26	9.0-10.0	20-21
27	Caudal somites 47-49; thymus	27	11	21-22
28	Caudal somites 50-52 (end of somite formation); cervical sinus closing; handplate; pulmonary, subclavian, basilar and vertebral arteries; Jacobson's organ; milk line; Mullerian ducts; parathyroids; neurohypophysis; olfactory lobe and nerve; vitreous body	28	11.6-15	22
29	Cervical sinus closed; lateral palatine processes; pentadactyle rudiments; semicircular canals; cochlea; pia mater and arachnoid layer; sympathetic ganglia and ramus anastomoticus; chondrification of vertebrae; appearance of sternum; cecum; milk hillocks; calyces	29	16.4-18.6	22
30	Median (premaxillary) palatine processes; sex differentiation; eyelids and plica semilunaris; testis differentiated; glomeruli and convoluted tubules in metanephros; appearance of presternum; brachiocephalic and left common carotid arteries; epiphysis; hair follicles; mammary gland primordia; dental lamina; enamel organs; coils of small intestine; anus open	30	19.4-24	28
31	Facial clefts closing; palate developing; heart myoblasts become spindle-shaped	31	25.0	30
32	Phalanges (3rd and 4th most prominent); fusion of palatine processes; mandible ossifies; elongation of nuclei in longitudinal muscle layer of esophagus and stomach	32	26.6-30	32.5
33	Facial clefts closed; palate completed; femur ossifies; coils of large intestine; humerus ossifies; ribs start to ossify; adrenal medulla; nasal chamber and nasal septum complete; cerebellum; muscle bundles	33	30-38	34.5
34	Growth of eyelids; gut withdrawn from umbilical cord; muscularis mucosae; bodies and arches of vertebrae start to ossify	34	40.0	36.5
35	Sealed eyelids	35		
36	Penis raphé	35	44.5	39
37	Prepuce, scrotum in male; labia majora, clitoris in female	35	60.0	44
38	Neuroglia present	35	70.0	46
39	Odontoid process ossifies	35	75.0	48
40	Intercalated discs appear	35	76.0	48
41	Seminal vesicles, prostate, Cowper's glands in male; oviducts, uteri and vagina in female	35	85.0	51
42	Intercalated discs extend across cardiac muscle fibers	35	89.0	52
43	Tonsil	35	90.0	52
44	Corpora quadrigemina	35	100.0	54.5
45	Nymphae (labia minora)	35	113.0	58.5
46	Ameloblasts and odontoblasts	35	120.0	61
47	Sternebrae start to ossify	35	125.0	62
48	Testis descending	35	128.0	62.5
49	Petrous portion of temporal last to ossify, dentine and enamel	35	130.0	63
50	Sulci and gyri in cerebrum	35	200.0	92
51	Testis entering inguinal canal	35	210.0	95
52	Eyelids separate	36		
53	Birth		250-300	98-140

/1/ Greatest length, neck length (spine length) or crown-rump length of embryo. /2/ Unless otherwise noted. /3/ Extra-embryonic length. /4/ 1st somite not delimited anteriorly. /5/ Apparent decrease in size may be attributed to torsion of embryo.

129. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: FROG

Data for embryo stages adapted from Shumway, W., Anat. Rec., 78:139-144, 1940. Larval stage data adapted from Taylor, A. C., and Kollros, J. J., Anat. Rec. 94:7-23, 1946. Values are principally for Rana pipiens, but may vary widely with different geographic strains and culture conditions.

	Organ, Tissue or Characteristic	Stage	Size mm	Age[1]
	Embryo			
1	Unfertilized egg	1	1.5-2	0
2	Fertilized egg; gray crescent	2	1.5-2	1
3	Two cells	3		3.5
4	Four cells	4		4.5
5	Eight cells	5		5.7
6	Sixteen cells	6		6.5
7	Thirty-two cells	7		7.5
8	Middle blastula	8		16
9	Late blastula	9		21
10	Early gastrula; dorsal lip stage	10		26
11	Middle gastrula; blastopore C- or U-shaped	11		34
12	Late gastrula; yolk plug; primitive gut	12		42
13	Early neurula; medullary plate defined	13		50
14	Mid-neurula; well-defined neural folds approaching each other; oral plate; anal pit; postanal gut	14		62
15	Late neurula; neural folds touch each other over most of their length; neurenteric canal; embryo rotates in jelly	15		67
16	Neural tube; ectoderm fused over it; oral sucker	16	3	72
17	Tail bud; nasal pit; dorsal sorts	17	3.5	84
18	Muscular response to stimulation of myotome; lens placode	18	4	96
19	Heart beats; pronephros functional; Rohon-Beard cells; thyroid evagination	19	5	118
20	Embryo hatched; gill circulation; lens vesicle	20	6	140
21	Mouth open; free swimming; cornea becoming transparent; olfactory nerve; two rudiments of ventral pancreas; lung rudiments	21	7	162
22	Circulation in tail fin; cartilaginous trabeculae; two gill slits are perforate; trabeculae carnae	22	8	192
23	Opercular folds and labial teeth appear; spontaneous respiratory activity of mouth begins; basal plate	23	8-9	216
24	Operculum closed on right side; adrenal cortex rudiment; respiratory rhythm begins	24	9-10	240
25	Operculum closed except for spiracle; rods and cones; germinal ridge; sucker regressed; rudiments of mesonephric tubules	25	10-11	284
26	Feeding begins; rudiments of adrenal medulla and of hind limb appear			
27	Lagena; neural lobe of hypophysis			
28	Limb bud of equal length and diameter; lateral motor column			
29	Ovarial sac; cartilage in synotic tectum			
30	Limb bud twice as long as it is broad; bent ventrad distally			
31	Flattened paddle at distal end of limb bud; scapular cartilage; ovary-testis distinguishable			
32	Foot paddle indented between toes 4 and 5			
33	Urinary bladder rudiment; measurable thyroid hormone output			
34	Separation of fat body from gonad; #spontaneous limb twitches			
35	All toes marked by indentation of the foot margin between them; rudiments of fungiform papillae of tongue			
36	Margin of fifth toe web directed toward toe 2			
37	Margin of fifth toe web directed toward toe 1			
38	Margin of fifth toe web directed toward the prehallux			
39	Rudiments of Harderian glands, and of skin glands			
40	First toe pads; hind limbs take part in swimming			
41	Nictitating membrane a low fold anterior to eyeball			
42	Some skin glands patent; peritoneal thickening presages oviduct			
43	Cloacal tail piece resorbed; corneal reflex			
44	Tail regression begins; skin windows form			
45	Skin windows perforate; forelimbs emerge; oral beaks lost			
46	Upper lid forms; first molt			
47	Conjunctival sac complete; lateral lines regressing			
48	Labial fringes completely lost; vasa efferentia			
49	Tympanic membrane outlined; tail stub of 1-2 mm			
50	Tail stub fully resorbed; oviduct extends nearly to cloaca			
51	Fully metamorphosed; gonads immature; urostyle			
52	Sexually mature			

	Organ, Tissue or Characteristic	Stage	Size mm	Age[1]
	Larva			
	Lagena	I	13	3
	Lagena; neural lobe of hypophysis	II	17	6
	Limb bud of equal length and diameter; lateral motor column	III	23	11
	Ovarial sac; cartilage in synotic tectum	IV	33	19
	Limb bud twice as long as it is broad; bent ventrad distally	V	39	23
	Flattened paddle at distal end of limb bud; scapular cartilage; ovary-testis distinguishable	VI	43	26
	Foot paddle indented between toes 4 and 5	VII	50	31
	Urinary bladder rudiment; measurable thyroid hormone output	VIII	53	34
	Separation of fat body from gonad; #spontaneous limb twitches	IX	56	36
	All toes marked by indentation of the foot margin between them; rudiments of fungiform papillae of tongue	X	58	40
	Margin of fifth toe web directed toward toe 2	XI	61	43
	Margin of fifth toe web directed toward toe 1	XII	64	47
	Margin of fifth toe web directed toward the prehallux	XIII	67	52
	Rudiments of Harderian glands, and of skin glands	XIV	70	58
	First toe pads; hind limbs take part in swimming	XV	72	62
	Nictitating membrane a low fold anterior to eyeball	XVI	73	64
	Some skin glands patent; peritoneal thickening presages oviduct	XVII	73	67
	Cloacal tail piece resorbed; corneal reflex	XVIII	74[2]	70
	Tail regression begins; skin windows form	XIX	73	72
	Skin windows perforate; forelimbs emerge; oral beaks lost	XX	70	74
	Upper lid forms; first molt	XXI	63	76
	Conjunctival sac complete; lateral lines regressing	XXII	44	79
	Labial fringes completely lost; vasa efferentia	XXIII	33	81
	Tympanic membrane outlined; tail stub of 1-2 mm	XXIV	26	84
	Tail stub fully resorbed; oviduct extends nearly to cloaca	XXV	25[3]	88
	Fully metamorphosed; gonads immature; urostyle	Juvenile	25-70	90-
	Sexually mature	Adult	60-110	1-3 yr

/1/ Age is expressed in hours (at 18°C) for embryo stages 1-25, in days (at 20°C) for succeeding stages. Ages for embryo stages 2 through 20 in hours at 20°C are : 0.5, 2.3, 3.2, 4.0, 4.8, 5.6, 7.0, 17.0, 22, 28, 30, 38, 43, 49, 52, 61, 76, 88 and 96, respectively. /2/ Maximum size highly variable. Tadpoles over 100 mm length reported. /3/ Size at end of metamorphosis variable. Range 16-30 mm.

130. SUMMARY, DEVELOPMENT CHARACTERISTICS: MAMMALS AND BIRDS

Hours and days are counted from the time of fertilization. In birds one day was added to observed incubation times; in mammals observed mating ages were reduced by the estimated number of hours necessary for the establishment of contact between egg and sperm (opossum 8, rabbit 14, hamster 8, rat 9, pig 8, sheep 6). In the monkey the ovulation age (Lewis-Hartman) was reduced by 2 hours. Values adapted from E. Witschi's "Development of Vertebrates," W. B. Saunders Co., 1956.

		Stage	Hawk	Chick	Sparrow	Opossum	Rabbit	Hamster	Rat	Swine	Sheep	Rhesus Monkey	Man
1	2	2 cells, hr		3		40	8	15	24	30	30	24	38
2	3	4 cells, hr		3 1/4		56	11	40	50	34	34	36	48
3		Implantation begins, da				6	7	4 1/2	6	7	10	9	6 1/2
4	12	Primitive streak, da	1 1/2-2	1 1/2-2	7-7 1/2	6 1/2-7	6 1/2-7	6 1/2-7	8 1/2-9	11-12	13	18-20	17-21
5	16	13-20 somite embryo, da	4 1/2	2 1/2	9	9	8	10 1/2	16	17	25	27	26
6	17	Tailbud forms, da		3 1/4	3 1/4	9 1/2	9 1/2	8 1/2	11 1/2	17	18	26	29
7	25	End of embryonic period, da	9	5	5	10	10	9	13	20	21	28	36
8	33/34	End of metamorphosis, da	13	8	7 1/2	12	14	13 1/2	16	24	32	40	60
9		Sex differentiation, da	12	6 1/2	6 1/2	15	13 1/2	13	13 1/2	21	28	36	45
10	35	Eyelids closed, da	23	13	11	12 1/4	19		17	32	42	48	70
11	36	Eyelids open, da		20	19				38		84		180
		Hatching or birth											
12		Age, da	35	21	13	12 1/2	32		22	112	150	164	267
13		Stage	35/36	36	35	35	35+	35	35	36	36	36	36
14		Weight, absolute, kg	0.012	.034	0.0017	0.13[1]	0.057	0.0022	0.0045	2.5	5	.450	3.2
15		Relative to mother, %		3	6	0.01	3	2.3	2.25	2.5	8	7.5	5.5

/1/ Grams.

	Cattle:[1]		Ayrshire[1]		Brown Swiss[1]		Guernsey[1]		Holstein[1,2]		Jersey[1,2]	
	Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
1	Birth	♂	33-40	73-89	43-50	95-110	29-41	65-90	42-47	92-104	22-29	49-64
2	1 wk	♂	34-43	76-94	45-53	100-117	34-41	75-90	46-49	101-109	25-29	56-65
3	2 wk	♂	39-49	86-108	53-59	116-130	41-47	90-103	48-54	106-120	28-35	62-77
4	3 wk	♂	42-57	92-127	60-68	133-150	45-51	99-113	53-65	116-144	33-38	73-83
5	4 wk	♂	52-65	114-143	68-83	151-183	49-57	108-125	57-73	125-162	36-43	79-96
6	5 wk	♂	58-77	128-169	78-92	173-204	59-65	130-143	64-79	141-174	41-48	90-106
7	6 wk	♂	68-88	150-195	86-99	190-218	66-70	145-155	66-86	145-190	49-56	107-123
8	7 wk	♂	75-97	165-213	96-106	211-234	74-76	164-168	75-96	165-213	57-64	126-142
9	8 wk	♂	82-102	180-225	102-117	227-259	84-86	186-190	92-107	202-236	63-77	140-169
10	3 mo	♀							96	211	64	141
11	6 mo	♀							176	389	127	281
12	9 mo	♀							254	561	193	426
13	1 yr	♀							315	697	233	514
14	2.5 yr	♀							525	1158	400	883
15	6-7 yr	♀							649	1433	477	1052

	Dog:		Basenjis		Beagle		Cocker spaniel		German shepherd[3]	
	Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb
16	Birth	♂	0.23-0.34	0.50-0.75	0.40	0.88	0.20-0.30	0.44-0.66	0.39-0.52	0.87-1.14
17		♀	0.26-0.30	0.57-0.66	0.30	0.66	0.20-0.31	0.44-0.68		
18	1 wk	♂	0.34-0.48	0.75-1.06	0.69	1.52	0.32-0.54	0.71-1.19	0.71-0.92	1.56-2.02
19		♀	0.34-0.51	0.75-1.12	0.56	1.23	0.32-0.57	0.71-1.26		
20	2 wk	♂	0.52-0.68	1.15-1.50	1.01	2.23	0.50-0.77	1.10-1.70	1.31-1.56	2.90-3.45
21		♀	0.52-0.71	1.15-1.56	0.80	1.76	0.50-0.77	1.10-1.70		
22	4 wk	♂	0.80-1.11	1.76-2.45	1.61	3.55	0.82-1.33	1.81-2.93	2.86-3.04	6.32-6.70
23		♀	0.70-1.14	1.54-2.51	1.26	2.78	0.86-1.25	1.90-2.76		
24	6 wk	♂	1.22-1.66	2.69-3.66	2.48	5.47	1.46-2.30	3.22-5.07	4.45-5.04	9.82-11.13
25		♀	1.06-1.64	2.34-3.61	1.79	3.95	1.54-2.14	3.39-4.72		
26	8 wk	♂	1.93-2.64	4.25-5.82	3.54	7.80	2.66-3.69	5.86-8.13	15.4-35.2	7.0-16.0
27		♀	1.76-2.92	3.88-6.44	2.53	5.58	2.30-3.26	5.07-7.19	17 6-39.6	8.0-18.0
28	10 wk	♂	2.72-3.90	5.99-8.60	4.59	10.12	3.52-4.62	7.76-10.18	20.9-47.3	9.5-21.5
29		♀	2.52-3.86	5.55-8.51	3.26	7.19	3.02-4.24	6.66-9.34	20.9-53.9	9.5-24.5
30	12 wk	♂	3.40-4.96	7.49-10.93	5.81	12.81	4.54-6.27	10.01-13.82	23.1-64.9	10.5-29.5
31		♀	3.52-4.88	7.76-10.76	4.22	9.31	3.98-5.36	8.77-11.81	24.1-61.6	10.9-28.0
32	14 wk	♂	4.64-6.41	10.23-14.13	6.98	15.38	5.39-7.63	11.88-16.82	26.4-81.4	12.0-37.0
33		♀	4.24-5.96	9.34-13.14	4.84	10.67	4.76-6.54	10.49-14.41	36.3-69.3	16.5-31.5
34	16 wk	♂	5.52-7.36	12.17-16.22	7.89	17.39	6.42-8.96	14.15-19.75	29.7-94.6	13.5-43.0
35		♀	5.07-6.88	11.17-15.16	5.45	12.01	5.32-7.28	11.73-16.05	36.3-83.6	16.5-38.0

	Goat:		Saanen, ♂		Saanen, ♀		Toggenburg, ♂		Toggenburg, ♀	
	Age		kg	lb	kg	lb	kg	lb	kg	lb
36	Birth		3.6(3.0-4.2)	7.9(6.6-9.3)	3.1(2.4-3.9)	6.9(5.3-8.6)	3.5(2.9-4.1)	7.7(6.4-9.0)	3.1(2.5-3.6)	6.8(5.6-8.0)
37	1 mo		7.2(6.0-8.4)	15.8(13.1-18.5)	6.7(5.4-8.0)	14.8(11.9-17.7)	6.8(5.6-7.9)	14.9(12.4-17.4)	6.4(5.4-7.3)	14.0(11.9-16.1)
38	2 mo		11.3(9.4-13.2)	25(21-29)	11.0(9.2-13.0)	24(20-28)	11.2(9.5-12.8)	25(21-28)	10.2(8.6-11.6)	23(20-26)
39	3 mo		15.0(12.1-17.8)	33(27-39)	14.6(11.8-17.3)	32(26-38)	15.0(12.5-17.4)	33(28-38)	13.7(12.0-15.5)	30(26-34)
40	6 mo		25(20-30)	54(43-65)	25(20-29)	54(44-64)	23(20-27)	51(44-59)	21(18-24)	46(39-53)
41	9 mo		31(26-35)	67(57-78)	30(24-35)	66(54-78)	27(23-32)	60(51-69)	25(22-29)	56(48-64)
42	1 yr		41(34-47)	90(76-104)	35(28-42)	78(63-93)	35(30-39)	77(67-87)	29(25-33)	64(55-73)
43	2 yr		58(44-72)	128(97-160)	54(44-64)	118(97-140)	48(39-57)	106(87-125)	45(37-53)	99(81-117)
44	3 yr		68(51-85)	149(112-187)	58(46-71)	129(101-157)	58(49-68)	128(108-149)	52(41-62)	114(91-136)
45	4 yr		82	180	60(49-72)	133(107-159)	71(62-80)	156(136-177)	52(43-61)	114(94-133)
46	5 yr		77	169	70(56-86)	155(119-190)	67(49-84)	147(108-185)	54(47-61)	120(104-135)

	Guinea Pig:		Cavia cutleri				Race B				Inbred Line		Random Breed	
	Age		♂		♀		♂		♀		♂		♂	
	da	g	oz	g	oz	g	oz	g	oz	Age da	g	oz	g	oz
47	Birth	50	1.8	50	1.8	80	2.8	80	2.8	Birth	80(56-99)	2.8(2.0-3.5)	95(75-130)	3.3(2.6-4.6)
48	10	70	2.5	70	2.5	90	3.2	90	3.2	13	130(88-165)	4.6(3.1-5.8)	170(105-230)	6.0(3.7-8.1)
49	20	110	3.9	110	3.9	130	4.6	130	4.6	23	165(110-220)	5.8(3.9-7.8)	225(145-310)	7.9(5.1-10.9)
50	40	160	5.6	160	5.6	200	7.0	200	7.0	33	265(170-360)	9.3(6.0-12.7)	345(215-475)	12.2(7.6-16.7)
51	60	210	7.4	200	7.0	280	9.9	250	8.8	113	475(340-610)	16.7(12.0-21.5)	570(395-750)	20.1(13.9-26.4)
52	80	260	9.2	230	8.1	360	12.7	330	11.6	173	585(460-710)	20.6(16.2-25.0)	720(530-910)	25.4(18.7-32.1)
53	100	300	10.6	260	9.2	440	15.5	400	14.1	233	650(520-775)	22.9(18.3-27.3)	815(605-1025)	28.7(21.3-36.1)
54	120	330	11.6	280	9.9	500	17.6	450	15.9	293	690(560-820)	24.3(19.8-28.9)	875(670-1070)	30.9(23.6-37.7)
55	140	360	12.7	300	10.6	550	20.8	530	18.7	353	710(585-835)	25.0(20.6-29.5)	910(790-1030)	32.1(27.9-36.3)
56	200	380	13.4	320	11.3	660	23.3	610	21.5	413	730(600-860)	25.7(21.1-30.3)	940(720-1160)	33.2(25.4-40.9)
57	240	390	13.8	340	12.0	710	25.0	670	23.6	473	745(615-875)	26.3(21.7-30.9)	950(660-1245)	33.5(23.3-43.9)
58	280	400	14.1	360	12.7	750	26.4	700	24.7	533	760(635-885)	26.8(22.4-31.2)	985(780-1190)	34.7(27.5-42.0)
59	320	410	14.5	380	13.4	790	27.8	720	25.4	593	765(645-885)	27.0(22.7-31.2)	990(780-1205)	34.9(27.5-42.5)
60	360	420	14.8	400	14.1	800	28.2	740	26.1	653	775(650-900)	27.3(22.8-31.7)	1000(810-1195)	35.3(28.6-42.1)
61	400	420	14.8	400	14.1	800	28.2	740	26.1	713	780(660-900)	27.5(23.3-31.7)	1020(785-1260)	36.0(27.7-44.4)

	Monkey:		Macaque		Marmoset, squirrel		Black-howler		Spider		White-faced	
	Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
62	Birth	♂	0.49(0.39-0.57)	1.08(0.85-1.47)			1.59	3.5	0.91	2	0.02	0.5
63		♀	0.47(0.33-0.64)	1.02(0.72-1.41)			(0.91-1.13)	(2-2.5)	(0.68-1.13)	(1.5-2.5)	(0.05-0.07)	(1-1.5)
64	Juvenile	♂	1.45(1.07-1.88)	3.19(2.34-41.4)			2.72	6	(2.27-2.72)	(5-6)	1.81	4
65		♀	1.42(0.89-1.80)	3.10(1.96-3.96)			2.27	5	1.81	4	(1.36-1.59)	(3-3.5)
66	"Young"-	♂	2.20(1.48-2.98)	4.83(3.25-6.56)	0.453	1			(3.62-5.44)	(8-12)	(2.72-3.17)	(6-7)
67	adult	♀	2.19(1.45-2.68)	4.81(3.19-5.90)			4.08(3.62-6.34)	(8-14)	(4.08-5.89)	(9-13)	(1.59-2.27)	(3.5-5)
68	"Old"-	♂	11.0(8.8-12.2)	24.1(19.4-26.7)	(0.57-0.79)	(1.25-1.75)	(6.34-8.15)	(14-18)	(6.8-8.6)	(15-19)	3.9(3.4-5.4)	8.5(7.5-12)
69	adult	♀	8.01(6.31-12.2)	17.6(13.9-26.8)	0.68(0.45-0.91)	1.5(1-2)	(4.98-7.47)		(11-16.5)	(16-24.5)	(6.34-8.61)	(14-19)

/1/ Data for first 8 weeks obtained by one investigator under conditions of ad libitum feeding of milk alone. /2/ Data for 3 months to 7 years obtained by another investigator under practical feeding conditions, hence show slower gains. /3/ Values in Lines 16-25 and 26-35 are from different sources.

	Mouse:	Black, piebald, ♂		Black, piebald, ♀		White, ♂	
	Age	g	oz	g	oz	g	oz
70	Birth	1.4(1.1-1.7)	0.05(0.04-0.06)	1.4(1.1-1.7)	0.05(0.04-0.06)		
71	2 da	6.1(4.4-7.7)	0.22(0.16-0.27)	6.1(4.5-7.7)	0.21(0.16-0.27)		
72	3 wk	8.0(5.6-10.4)	0.28(0.20-0.37)	8.3(6.3-10.4)	0.29(0.22-0.37)	8.2(7.3-8.9)	0.29(0.26-0.32)
73	4 wk	12.3(9.8-14.7)	0.43(0.35-0.52)	12.1(9.7-14.5)	0.43(0.34-0.51)	12.4(11.6-13.3)	0.44(0.41-0.47)
74	6 wk	19.1(15.3-22.9)	0.67(0.54-0.81)	18.3(16.0-20.6)	0.65(0.57-0.73)	19.6(18.7-20.5)	0.69(0.66-0.72)
75	8 wk	22.6(18.8-26.4)	0.80(0.66-0.93)	19.7(16.5-22.8)	0.70(0.58-0.80)	22.2(20.9-23.5)	0.78(0.74-0.83)
76	12 wk	25.9(22.2-29.5)	0.91(0.79-1.04)	23.6(19.0-28.2)	0.83(0.67-0.99)	25.3(24.2-26.4)	0.89(0.85-0.93)
77	16 wk	28.6(21.1-36.0)	1.01(0.74-1.27)	26.5(20.1-33.0)	0.94(0.71-1.16)	27.2(25.7-28.7)	0.96(0.91-1.01)
78	20 wk	30.0(21.8-38.3)	1.06(0.77-1.35)	29.0(21.8-36.1)	1.02(0.77-1.27)	27.8(26.4-29.2)	0.98(0.93-1.03)
79	24 wk	33.1(25.7-40.5)	1.17(0.91-1.43)	32.3(25.5-39.1)	1.14(0.90-1.38)	27.6(26.3-28.8)	0.97(0.93-1.02)
80	28 wk					28.0(26.3-29.7)	0.99(0.93-1.05)
81	32 wk					29.4(28.2-30.5)	1.04(0.99-1.08)

	Rat:	Sherman, albino, small, ♂		Sherman, albino, small, ♀		Sherman, albino, large, ♂		Sherman, albino, large, ♀	
	Age	g	oz	g	oz	g	oz	g	oz
82	Birth	5.5(4.9-6.1)	0.19(0.17-0.22)	5.5(4.8-6.2)	0.19(0.17-0.22)	6.1(4.9-7.7)	0.21(0.17-0.27)	5.8(4.9-6.6)	0.20(0.17-0.23)
83	1 wk	13.4(10-17)	0.47(0.35-0.60)	13.1(10.5-16)	0.46(0.37-0.56)	17.5(12.5-23)	0.6(0.4-0.8)	16.2(13-19)	0.57(0.45-0.67)
84	2 wk	25(21-30)	0.88(0.74-1.06)	25(20-30)	0.88(0.71-1.06)	37(29-45)	1.3(1.0-1.6)	34(28-40)	1.2(1.0-1.4)
85	4 wk	61(51-71)	2.2(1.8-2.5)	56(48-63)	2.0(1.7-2.2)	93(78-108)	3.3(2.8-3.8)	80(68-91)	2.8(2.4-3.2)
86	6 wk	121(106-136)	4.3(3.7-4.8)	100(89-111)	3.5(3.1-3.9)	188(157-218)	6.6(5.6-7.7)	147(128-166)	5.2(4.5-5.9)
87	8 wk	177(149-205)	6.2(5.3-7.2)	130(122-137)	4.6(4.3-4.8)	274(231-317)	9.7(8.1-11.2)	196(169-222)	6.9(6.0-7.8)
88	10 wk	222(191-254)	7.8(6.7-9.0)	154(145-163)	5.4(5.1-5.8)	339(291-386)	12.0(10.3-13.6)	227(199-256)	8.0(7.0-9.0)
89	12 wk	252(213-291)	8.9(7.5-10.3)	169(159-179)	6.0(5.6-6.3)	393(328-458)	13.9(11.6-16.2)	251(232-280)	8.9(8.2-9.9)
90	15 wk	285(241-329)	10.0(8.5-11.6)	185(165-205)	6.5(5.8-7.2)	440(379-501)	15.5(13.4-17.7)	274(238-310)	9.6(8.4-10.9)
91	20 wk	326(278-373)	11.5(9.8-13.2)	202(178-225)	7.1(6.3-7.9)	490(423-556)	17.3(14.9-19.6)	303(270-335)	10.7(9.5-11.8)
92	30 wk	376(335-417)	13.3(11.8-14.7)	230(205-255)	8.1(7.2-9.0)			335(298-373)	11.8(10.5-13.2)
93	40 wk			240(215-265)	8.5(7.6-9.3)			358(311-404)	12.6(11.0-14.3)

	Rat:	Wistar, albino, ♂		Wistar, albino, ♀		Wild Norway, ♂		Wild Norway, ♀	
	Age	g	oz	g	oz	g	oz	g	oz
94	Birth	5.6(4.5-6.7)	0.2(0.16-0.23)	5.3(4.5-6.1)	0.18(0.16-0.22)				
95	3 wk	43(38-49)	1.5(1.3-1.7)	41(34-48)	1.4(1.2-1.7)				
96	4 wk	52	1.8	55	1.9				
97	6 wk	110	3.9	97	3.4	85(67-112)	3.0(2.4-3.9)	104(79-142)	3.7(2.8-5.0)
98	8 wk	170	6.0	128	4.5	170(127-218)	6.0(4.5-7.7)	152(120-200)	5.4(4.2-7.1)
99	10 wk	200	7.1	147	5.2				
100	12 wk	225(182-286)	7.9(6.4-10.1)	165(143-187)	5.8(5.0-6.6)	237(176-299)	8.4(6.2-10.6)	194(149-249)	6.8(5.2-8.8)
101	15 wk	251	8.8	180	6.3	289(217-361)	10.2(7.7-12.7)	230(178-291)	8.1(6.3-10.3)
102	17 wk					330(251-408)	11.6(8.9-14.4)	260(203-327)	9.2(7.2-11.5)
103	20 wk	280	9.9	200	7.1				
104	23 wk					388(302-472)	13.7(10.7-16.7)	311(245-383)	11.0(8.6-13.5)
105	28 wk					424(335-509)	15.0(11.8-18.0)	348(276-423)	12.3(9.7-14.9)
106	35 wk					446(358-531)	15.7(12.6-18.7)	376(300-452)	13.3(10.6-15.9)
107	40 wk	342	12.1	245	8.6	460(374-545)	16.2(13.2-19.2)	397(319-473)	14.0(11.3-16.7)
108	45 wk					468(385-551)	16.5(13.6-19.4)	413(333-488)	14.6(11.8-17.2)
109	50 wk					474(392-556)	16.7(13.8-19.6)	424(344-497)	15.0(12.1-17.5)
110	52 wk	364(263-465)	12.8(9.3-16.4)	243(196-290)	8.6(6.9-10.2)				
111	57 wk					477(397-558)	16.8(14.0-19.7)	433(352-507)	15.3(12.4-17.9)

	Swine:	Berkshire				Duroc-Jersey		Yorkshire	
	Age	kg	lb	kg	lb	kg	lb	kg	lb
112	Birth	1.84(1.34-2.17)		4.06(2.95-4.78)	2.74(2.73-2.76)	6.04(6.02-6.08)			
113	1 wk	2.58(2.17-3.10)		5.69(4.78-6.83)	3.30(2.96-3.64)	7.27(6.52-8.02)			
114	2 wk	4.32(3.47-4.91)		9.52(7.65-10.82)	5.25(4.75-5.74)	11.57(10.47-12.65)			
115	3 wk	7.02(5.78-8.14)		15.47(12.74-17.94)	8.37(7.66-9.03)	16.38(15.07-17.70)			
116	4 wk	9.85(8.43-12.60)		21.70(18.58-27.8)	8.84(8.55-9.12)	19.48(18.84-20.10)			
117	5 wk	14.02(12.30-17.00)		30.9(27.1-37.5)	13.13(12.80-13.45)	28.9(28.2-29.6)			
118	6 wk	18.31(16.14-21.36)		40.4(35.6-47.1)	16.96(16.50-17.45)	37.4(36.4-38.5)			
119	7 wk	23.16(21.02-27.04)		51.0(46.3-59.6)	20.94(20.43-21.45)	46.2(45.0-47.3)			
120	8 wk	27.45(24.32-31.36)		60.5(53.6-69.1)	24.21(23.86-24.55)	53.4(52.6-54.1)		11.8	26
121	10 wk				27.37(26.86-28.38)	60.4(61.1-83.8)		16.3	36
122	12 wk				50.8(50.0-51.5)	111.9(110.2-113.5)		20.4	45
123	14 wk							27.2	60
124	16 wk							35.8	79
125	18 wk							46.2	102
126	20 wk							47.6	105
127	22 wk							65.2	144
128	24 wk							78.8	174
129	26 wk							79.3	175
130	28 wk							87.9	194

	Chicken:	Cornish, ♂		Cornish, ♀		White Leghorn, ♂		White Leghorn, ♀		New Hampshire, ♂		New Hampshire, ♀	
	Age	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
131	Birth	0.032	0.07	0.032	0.07	0.036	0.08	0.036	0.08	0.041	0.09	0.036	0.08
132	1 wk	0.059	0.13	0.059	0.13	0.059	0.13	0.073	0.16	0.086	0.19	0.082	0.18
133	2 wk	0.109	0.24	0.105	0.23	0.123	0.27	0.118	0.26	0.154	0.34	0.154	0.34
134	3 wk	0.182	0.4	0.172	0.38	0.191	0.42	0.195	0.43	0.272	0.60	0.250	0.55
135	4 wk	0.268	0.59	0.256	0.56	0.268	0.59	0.272	0.60	0.404	0.89	0.363	0.80
136	5 wk					0.354	0.78	0.367	0.81	0.563	1.24	0.504	1.11
137	6 wk					0.449	0.99	0.436	0.96	0.735	1.62	0.640	1.41
138	7 wk					0.603	1.33	0.549	1.21	0.934	2.06	0.807	1.78
139	8 wk	0.727	1.6	0.636	1.4	0.689	1.52	0.640	1.41	1.152	2.54	0.948	2.09
140	9 wk					0.875	1.93	0.721	1.59	1.325	2.92	1.107	2.44
141	10 wk					0.944	2.08	0.776	1.71	1.628	3.59	1.284	2.83
142	12 wk	1.272	2.8	1.045	2.3	1.243	2.74	0.934	2.06	1.849	4.45	1.551	3.42
143	14 wk							1.107	2.44	2.554	5.63	1.828	4.03
144	16 wk	1.727	3.8	1.318	2.9			1.270	2.80	2.994	6.60	2.019	4.45
145	18 wk							1.402	3.09	3.293	7.26	2.254	4.97
146	20 wk	2.09	4.6	1.545	3.4			1.551	3.42	3.375	7.44	2.309	5.09

	Turkey:	Broad-breasted bronze, ♂		Broad-breasted bronze, ♀		Beltsville, small white, ♂		Beltsville, small white, ♀	
	Age	kg	lb	kg	lb	kg	lb	kg	lb
147	Birth	0,054	0,12	0,050	0,11	0,045	0,10	0,045	0,10
148	1 wk	0,113	0,25	0,109	0,24	0,095	0,21	0,086	0,19
149	2 wk	0,204	0,45	0,195	0,43	0,181	0,40	0,163	0,36
150	4 wk	0,585	1,29	0,517	1,14	0,472	1,04	0,404	0,89
151	6 wk	1,252	2,76	0,998	2,20	0,921	2,03	0,721	1,59
152	8 wk	2,028	4,47	1,651	3,64	1,483	3,27	1,148	2,53
153	10 wk	2,939	6,48	2,354	5,19	2,205	4,86	1,674	3,69
154	12 wk	4,037	8,90	3,166	6,98	2,726	6,01	2,087	4,60
155	14 wk	4,922	10,85	3,715	8,19	3,357	7,40	2,608	5,75
156	16 wk	6,214	13,70	4,604	10,15	4,264	9,40	3,062	6,75
157	18 wk	6,985	15,40	5,121	11,29	4,704	10,37	3,357	7,40
158	20 wk	8,328	18,36	5,851	12,90	5,643	12,44	3,742	8,25
159	22 wk	8,850	19,51	6,083	13,41				
160	24 wk	10,614	23,40	6,836	15,07	7,438	16,20	4,382	9,66
161	26 wk	11,506	25,37	7,307	16,11	8,038	17,72	4,631	10,21
162	28 wk	12,633	27,85	7,625	16,81	9,008	19,86	4,760	10,45
163	30 wk					9,113	20,09	5,085	11,21
164	35 wk	14,610	32,21	7,793	17,18				
165	40 wk	14,814	32,66	8,437	18,60				

	Age	Duck, white pekin		Goose, pilgrim				Quail, bob-white	
		kg	lb	♂ kg	♂ lb	♀ kg	♀ lb	kg	lb
166	Birth	0,059	0,13			0,07	0,17	0,004	0,01
167	1 wk	0,150	0,33	0,227	0,5	0,227	0,5	0,018	0,04
168	2 wk	0,458	1,01	0,635	1,4	0,589	1,3	0,027	0,06
169	3 wk	0,744	1,64	1,270	2,8	1,270	2,8	0,045	0,10
170	4 wk	1,148	2,53	1,905	4,2	1,769	3,9	0,063	0,14
171	5 wk	1,506	3,32	2,404	5,3	1,814	4,0	0,082	0,18
172	6 wk	2,005	4,42	3,039	6,7	2,585	5,7	0,095	0,21
173	8 wk	2,758	6,08	3,946	8,7	3,447	7,6	0,132	0,29
174	10 wk			4,264	9,4	3,719	8,2		
175	12 wk			5,035	11,1	4,218	9,3	0,159	0,35
176	16 wk			5,352	11,8	4,672	10,3	0,172	0,38

		Lizard[4]						Snake[5]			
		Black footless		Desert night		Skink, western		Blacksnake, pilot		Cottonmouth		Greensnake, smooth	
		Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm
177		♂♀ <1 yr	(46-82)	♂♀ Birth	23(22-24)	♂♀ Birth	26(25-26)	♂♀ Birth	307(267-331)	♂♀ 8 mo	228	♂♀ 9 mo	152
178		2 yr	(82-120)	1 yr	29	4 mo	40(37-43)	46 da	330	5 yr 8 mo	1115	♂ 21 mo	356
179		3 yr	(120-160)	2 yr	36	6 mo	45(41-49)	77 da	356	8 yr 3 mo	1280	♀ 21 mo	406
180		Adult	(>160)	♂ 3 yr	(38-39)	10 mo	45	108 da	403(343-545)	9 yr 1 mo	1308	♀ 33 mo	559
181				♀ 3 yr	(42-43)	11 mo	50			10 yr 2 mo	1320		
182						20 mo	62			11 yr 2 mo	1371		
183						24 mo	65			12 yr 2 mo	1397		

		Snake[5] (continued)								Turtle	
		Massasauga, eastern		Racer, western striped		Rattlesnake, great basin		Water snake, queen		Terrapin, diamondback[6]		Turtle, common box[7]	
		Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm
184	♂♀ Birth	233		♂ 1 yr	627(579-655)	♂ 1 yr	457	♂♀ Birth	183(166-225)	♂♀ Birth	(18-36)	♀ Birth	29-30
185	1 yr	375		♀ 1 yr	587(538-622)	♀ 1 yr	450(419-503)	3 mo	231(196-255)	1st season	(30-61)	♀ 30 yr	93
186	3 yr	541		♂ 2 yr	790	♂ 2 yr	557(492-627)	1 yr	325(256-375)	2nd season	(54-87)	41 yr	127
187	Adult	637(541-731)		♂ 3 yr	864(807-919)	♀ 2 yr	554(530-574)	♂> 2 yr	529(375-692)	3rd season	(75-107)	64 yr	138
188				♂ 4 yr	833	♂ 3 yr	655(609-711)	♀> 2 yr	584(375-787)	4th season	(91-115)		
189				♀ 4 yr	894(883-904)	♂ 4 yr	732			5th season	(103-118)		
190				♂ 5 yr	859	♀ 4 yr	663(642-681)			6th season	(110-115)		
191						♂ 6 yr	770(724-815)						
192						♀ 6 yr	766						

	Fish:	Bass, rock		Carp		Catfish, channel		Crappie, black		Drum, fresh-water		Herring, lake		Paddlefish	
	Age	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
193	1 yr	0,006	0,013	0,09	0,198	0,045	0,099	0,006	0,013	0,036	0,079	0,023	0,051	0,077	0,170
194	2 yr	0,028	0,062	0,45	0,992	0,135	0,298	0,045	0,099	0,135	0,298	0,04	0,088	1,35	2,975
195	4 yr	0,065	0,143	1,8	3,967	0,23	0,507	0,255	0,562	0,60	1,324	0,17	0,375	2,27	5,0
196	6 yr	0,165	0,364	2,5	5,510	0,68	1,50	0,37	0,816	1,18	2,601	0,23	0,507	3,40	7,494
197	8 yr	0,255	0,562	3,2	7,053	1,63	3,593	0,57	1,256	2,04	4,496	0,53	1,169	5,0	11,0
198	10 yr	0,38	0,838	5,1	11,240	4,3	9,477	0,68	1,499	5,10	11,24	0,71	1,565	6,8	14,99
199	Maximum	0,595	1,311	38	84	24	53	1,35	2,975	6,97	15,36	1,25	2,755	74	163

	Fish: (continued)	Perch, yellow		Pike		Salmon, Atlantic		Sturgeon, lake		Sunfish, bluegill		Trout, lake		Whitefish, Lake Erie	
	Age	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
200	1 yr	0,003	0,007	0,09	0,198	0,011	0,024	0,068	0,150	0,005	0,011	0,03	0,070	0,03	0,070
201	2 yr	0,01	0,070	0,27	0,595	0,033	0,073	0,136	0,299	0,026	0,057	0,14	0,309	0,085	0,187
202	4 yr	0,11	0,242	1,10	2,42	4,54	10,01	0,39	0,859	0,07	0,154	0,45	0,992	0,70	1,543
203	6 yr	0,23	0,507	2,10	4,63	16,0	35	0,72	1,587	0,17	0,375	1,13	2,49	1,36	2,997
204	8 yr	0,29	0,639	2,95	6,50			1,0	2,204	0,34	0,749	1,95	4,30	2,27	5,003
205	10 yr	0,37	0,815	4,50	9,92			1,4	3,09	0,34	0,749	3,82	8,42	2,78	6,127
206	Maximum	1,91	4,21	28	62	47	104	50	110	1,96	4,320	36	79	4,88	10,76

/4/ Snout-vemt measurement. /5/ Total length measurement. /6/ Plastron measurement. /7/ Carapace measurement.

Values for organs are averages of fresh weight, in grams, determined as quickly as possible after removal. Body weight values, in kilograms, are averages, and are included only to show a relationship between average organ weights and average total body weights. When a single value for an organ weight is reported, it is an average for both sexes. When a value is a weight averaged over a period of two or more years, it is given at the earliest age of the period covered.

	Age		Body Weight	Adrenals	Brain	Heart	Hypophysis	Intestines	Kidneys	Liver	Lungs	Pancreas	Pineal Body	Spleen	Stomach[1]	Thymus	Thyroid[2]	Epididymis	Prostate	Seminal Vesicles	Testes	Ovaries	Uterus	Uterine Tubes
			kg	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g	g
1	Birth	♂	3.54	9.01	353	20	0.121	142	24	134	52	2.77	0.008	9.4	6.5	11.2	2.09(6.6)	0.24	0.82	0.050	0.67			
2		♀	3.43	9.03	341	19		149	22	137	51			9.4								0.29	4.70	0.29
3	0-3 mo	♂	5.92	4.66	435	19	0.161		30	143	69	3.54	0.044	14.6	10.9	19.3	1.71(3.18)	0.42	0.9	0.052	0.91			
4		♀	5.62	4.60	411	17			27	133	64			11.4								0.63	2.88	0.26
5	3-6 mo	♂	8.4	3.61	600	27			43	184	94	5.38		18.9	14.1	22.9	2.11(4.4)				1.12			
6		♀	7.9	4.37	534	25			37	178	93			15.9								0.45	3.00	
7	6-12 mo	♂	10.4	4.97	877	37			61	241	135	9.24		24	18.3	22.1	2.04(3.44)				1.39			
8		♀	10.6	4.60	726	33			55	250	128			21								0.74	4.83	
9	1-2 yr	♂	12.2	3.68	971	47		409	74	343	170	13.54	0.053	32	27.1	26.0	2.53(5.24)	0.34	1.2	0.08	1.48			
10		♀	11.9	3.19	894	42		375	69	322	175			29								0.98	4.01	0.29
11	2-3 yr	♂	14.4	5.62	1076	59	0.232		94	459	246	19	0.081	44	37.9[3]	25.9	3.40(9.13)				1.93			
12		♀	13.8	3.97	1012	55			91	429	244			41								1.12	2.30	
13	3-4 yr	♂	16.3		1279	71		648	101	531	305			49		26.4	4.9(11.22)	0.41	1.1		1.64			
14		♀	16.2		1076	66		383	105	491	266			47										
15	4-5 yr	♂	18.5		1290	78	0.224		111	567	314	22	0.098	48	51.8[4]	24.4	5.24(15.15)							
16		♀	18.0		1156	75			116	559	322			45								1.90	3.29[5]	
17	5-6 yr	♂	20.6	4.92	1275	89		691	108	592	261			57		23.3		0.50	1.3	0.099	1.67			
18		♀	20.0	5.02	1206	83			116	591	320			50										
19	6-7 yr	♂	22.7		1313	98	0.299		155	661	400	29	0.131	67		26.0	7.05(14.4)							
20		♀	22.2		1225	89			122	604	358			47										
21	7-8 yr	♂	25.1		1338	102			147	691	366			63		33.6								
22		♀	24.6		1265	96		559	134	683	404			56								3.30	4.30	0.49
23	8-9 yr	♂	28		1294	128	0.366		141	808	405	27		74		27.7	9.3(18.34)							
24		♀	27		1208	104			139	733	382			69										
25	9-10 yr	♂	31		1360	118			167	804	376			70		28.1								
26		♀	30		1226	125			157	863	358			66										
27	10-11 yr	♂	33	6.86	1378	137	0.378		184	931	475	29	0.156	90	90[7]	28.9	8.69(23.2)	0.73	1.9	0.120	2.0			
28		♀	34	7.40	1247	144			189	905	571			112										
29	11-12 yr	♂	37		1348	149			178	902	466			80		30.8								
30		♀	38		1259	127			143	840	535			83										
31	12-13 yr	♂	41		1383	154	0.460		185	987	459	35		85		23.6	14.8(24.7)	0.84	3.3		6.96			
32		♀	43		1256	131			193	1048	682			101										
33	13-14 yr	♂	46		1382	172		1000	211	1103	505			107		34.0					7.17[8]			
34		♀	46		1243	164			188	998	602			94								4.12[8]	11.60[8]	
35	14-15 yr	♂	52		1356	203			250	1166	693	68		109		26.5	14.5(26)	1.64	4.3	0.90	15.56			
36		♀	50		1318	184			226	1209	517			127								6.03	32	1.05
37	15-16 yr	♂	58	9.47	1407	203		1460	251	1228	692			145		28.8								
38		♀	52	11.38	1271	215			245	1349	709			131										
39	16-17 yr	♂	62		1419	234	0.520		253	1448	747	85	0.137	166	129[9]		16.6(28)		8.8		23.5			
40		♀	53		1300	243			261	1414	627			172										
41	17-18 yr	♂	65		1409	252			297	1515	777			148										
42		♀			1254	228			270	1417	695			123										
43	18-19 yr	♂	67		1426	260		1527	303	1702	848			169			18.3(29)							
44		♀	55		1312	242			276	1541	655			151										
45	19-20 yr	♂	69		1430	283			295	1570	1036			153										
46		♀			1294	257			272	1433	785			138								7.87[10]	47.0[10]	
47	20-30 yr	♂	71	13.75	1355	312	0.625	1600	312	1838	953		0.171	204		19.9	25(38)	4.0	16.6		28.3			
48		♀	56	13.80	1220	273			257	1437	793			168								10.16	77.5	2.13
49	30-40 yr	♂	72	11.41	1365			1570	323	1872	1169			168		19.7					27.2			
50		♀	60	11.57	1228			1550	250	1462	886			164								9.25	78.0	
51	40-50 yr	♂		11.52	1357			1800	316	1888				179		18.7					27.0			
52		♀	65	10.17	1227				258	1570				172								6.15	100.5	
53	50-60 yr	♂		12.48	1360				294	1848				127							27.4			
54		♀	67	12.01	1212				254	1464				133								5.73	95.8	
55	60-70 yr	♂		13.93	1319			1600	293	1728				132		13.4					24.3			
56		♀	65	12.95	1194				218	1400				129								2.87	63.3	
57	70-80 yr	♂		11.85	1290			1500	253	1426				123							21.6			
58		♀	61	10.42	1145			1400	236	1263				121								3.99	59.0	

/1/ Body weights of the individuals whose organ weights are given in this column were considerably lower than those shown in the body weight column for the various age groups. /2/ Normal thyroid values followed, in parentheses, by values for thyroid weight in geographical goiter areas. /3/ 2-4 yr. /4/ 4-7 yr. /5/ 3-5 yr. /6/ 6-10 yr. /7/ 7-14 yr. /8/ 11-14 yr. /9/ 14-20 yr. /10/ 15-20 yr.

133. BODY AND ORGAN WEIGHTS: VERTEBRATES

Values are based on fresh weight for adult organs, determined immediately after death of the organism, and are grams/100 grams body weight.

	Species	Sex and Number	Body wt. kg	Adrenals g/100g	Brain g/100g	Eyes g/100g	Heart g/100g	Kidneys g/100g	Liver g/100g	Lungs g/100g	Spleen g/100g	Stomach & Intestines g/100g	Thyroid g/100g
						Mammalia							
1	Man (Homo sapiens)												
2	Australian aborigine	♂1	76	0.005	1.77								0.005
3	Chinese	♂1	84	0.009	1.76		0.66	0.37	2.43		0.21		0.02
4	Filipino	♂1	43		2.57		0.46						0.06
5	Indian, Maya Quiche	♂1	42	0.03	3.02		0.52	0.44	2.48	3.13	0.14		0.08
6	Indian, Maya Quiche	♀1	46	0.02	2.18		0.49						0.02
7	Negro	♂7	47	0.03	2.73		0.81	0.51	2.81				0.06
8	White, American	♂7	67	0.02	1.96		0.42	0.41	2.30	0.73	0.25		0.04
9	White, European	♂4	69	0.03	2.53		0.64						0.03
10	Agouti, brown (Dasyprocta punctata)	♂9♀5	2.6	0.03	0.58	0.50	0.51	0.59	2.84	0.22			
11	Anteater (Cyclops didactylus)	♂1	0.09	0.84	4.77								
12	Anteater (Tamandua tetradactyla)	♂4	2.2		1.09		0.03	0.82	2.64	1.05	0.14		
13	Armadillo (Dasypus novemcinctus)	♂9♀2	3.3	0.03	0.25		0.28	0.48		0.70	0.22		0.009
14	Ass (Equus asinus)	♀1	150	0.01	0.27		0.55	1.04	0.84	0.83	0.39		0.006
15	Bat, vampire (Desmodus rotundus)	♂9♀	0.028	4.04	3.34								0.04
16	Bear, brown (Ursus americanus)	♂1	550	0.001				0.03					0.004
17	Bear, grizzly (U. horribilis)	♀1	140	0.04	0.16		0.79	0.38			0.21		0.04
18	Beaver (Castor canadensis)	♂1♀1	5	0.009	0.45		0.43	1.08	3.03	0.97			
19	Bison, American (Bison bison)	♀1	55	0.01	0.61	0.08	0.66	0.47	1.27	2.17	0.27		0.09
20	Buffalo, African (Syncerus caffer)	♂3♀1	700	0.005	0.09	0.008	0.47	0.24	0.98	0.94	0.33	20.90	0.005
21	Bushbok (Tragelaphus scriptus)	♂1♀1	44	0.01	0.37	0.11	0.76	0.40	1.95	1.64	0.26	12.62	0.01
22	Camel, bactrian (Camelus bactrianus)	♂1	450	0.005	0.12	0.02					0.08		
23	Caribou, ground (Rangifer arcticus)	♂3♀1	98	0.004	0.30	0.04	0.90	0.13	1.83	2.10	0.26		
24	Cat, domestic (Felis catus)	♂7♀3	3.3	0.02	0.77	0.32	0.45	1.07	3.59	1.04	0.29	10.37	0.01
25	Cattle, Holstein (Bos taurus)	♂5	900	0.005	0.05		0.37	0.20	0.92	0.69	0.15	3.14	0.010
26	Cattle, Holstein (B. taurus)	♀198	600	0.006	0.07		0.37	0.24	1.20	0.72	0.16	4.83	0.006
27	Cheetah (Acinonyx jubatus)	♂2	21	0.009	0.39	0.16	0.51	0.47	3.22	1.16	0.15		0.02
28	Chimpanzee (Pan troglodytes)	♂1	52	0.02	0.84		0.48						0.009
29	Chimpanzee (P. troglodytes)	♀1	44	0.02	0.74		0.50	0.48	2.75	1.36		14.09	0.01
30	Chipmunk (Tamias striatus)	♂2	0.07	0.04	0.96	0.74	7.96	0.10	7.4	0.96	0.29	6.2	0.04
31	Costi (Nasua nasua)	♂2	5.1	0.009	0.66	0.04	0.38	0.08	1.63	0.47	0.07		0.03
32	Coyote (Canis latrans)	♀2	8.5				0.85	0.94	3.44	0.72	0.17		
33	Deer, white-tailed(Odocoileus virginianus)	♂1	65		0.32		0.97		1.57				
34	Dog (Canis familiaris)	♂2♀2	13	0.01	0.59	0.10	0.85	0.30	2.94	0.94		4.83	0.02
35	Elephant (Loxodonta africana)	♀1	6600	0.01	0.08	0.001	0.39	0.27	1.62	2.08		13.88	0.01
36	Fox, gray (Urocyon cinereargenteus)	♂1	3.8	0.01	0.99	0.11	0.58	0.46	1.35	0.51		11.31	
37	Fox, red (Vulpes fulva)	♀1	4.6	0.01	1.15	0.09	0.90						0.003
38	Gazelle (Gazella thomsoni)	♂2	24	0.008	0.38	0.11	1.00	0.43	2.15	1.15			0.007
39	Giraffe (Giraffa camelopardalis)	♂1	1200	0.006	0.06	0.01	0.41	0.18	1.56	0.99	0.18	10.65	0.005
40	Goat (Capra hircus)	♀1	28		0.41	0.11			1.90				
41	Gorilla (Gorilla gorilla)	♂1	180	0.02									0.003
42	Guinea pig (Cavia porcellus)	♂58	0.26	0.07	1.33		0.53	1.17	5.14	1.18			
43	Guinea pig (C. porcellus)	♀10	0.43	0.08	0.92	0.24	0.39	0.86	3.86	1.07	0.21		0.02
44	Hamster, golden (Mesocricetus auratus)	♂2♀2	0.12	0.02	0.48	0.18	0.47	0.53	5.16	0.46			0.006
45	Hare, African (Lepus capensis)	♀1	2.9	0.02	0.35	0.25	1.02	0.42	1.77	0.61		10.07	0.006
46	Hippopotamus (Hippopotamus amphibius)	♀1	1350	0.004	0.05	0.003	0.34	0.23	1.75	0.84	0.23	27.70	0.008
47	Horse, Percheron (Equus caballus)	♂1	635	0.006	0.10	0.02	0.88	0.27	1.34	0.90	0.54		0.004
48	Horse, Percheron (E. caballus)	♀1	770	0.004	0.08	0.02	0.61	0.23	0.87	0.70	0.20		0.007
49	Hyena, spotted (Crocuta crocuta)	♂2	62	0.02	0.28	0.06	0.72	0.64	5.12	10.92		10.91	0.01
50	Hyrax (Heterohyrax brucei)	♂1	0.75	0.02	1.38		0.48	0.86	4.20	0.74		34	0.01
51	Jackal (Canis mesomelas)	♂2	2.8	0.02	1.61	0.24	0.75	0.81	4.30	1.05		10.81	0.03
52	Jaguar (Felis onca)	♀1	34	0.02	0.43	0.05	0.54	0.48	2.59	1.67	0.18		0.004
53	Kinkajou (Potos flavus)	♂1	2.6	0.007	1.18	0.07	0.54		3.76	2.99			0.02
54	Lemming, rock (Dicrostonyx rubricatus)	♂4	0.05	0.03	0.17	0.28	0.59	1.48	5.05	1.59	0.40		0.008
55	Leopard (Panthera pardus)	♂1	48	0.01	0.28	0.06	0.42		1.87	1.04	0.22		0.10
56	Lion (P. leo)	♂4	125	0.01	0.19		0.85			0.57			
57	Lion (P. leo)	♀3	97	0.01	0.20	0.04	0.54	0.53	3.24	2.06	0.22		
58	Lynx (Lynx baileyi)	♂1	7.4	0.08				0.33					0.004
59	Manatee (Trichechus manatus)	♂1	425		0.08	0.001	0.29		1.30	0.72			0.01
60	Manatee (T. manatus)	♀1	560	0.002		0.01	0.22	0.24	1.12	0.67			0.01
61	Mole (Scalopus aquaticus)	♂1	0.04	0.04	2.93		0.69	1.59	3.91	1.86			0.02
62	Mongoose (Ichneumia albicauda)	♂1	4.4	0.01	0.64	0.09	0.64	0.79	1.39	1.32		6.25	0.004
63	Monkey, blackhowler(Alouatta palliata)	♂9♀8	6.2	0.01	0.81		0.33	0.58	3.25	0.63	0.74		
64	Monkey, rhesus (Macaca mulatta)	♂4	3.3	0.02	2.78	1.06	0.38		2.09				0.02
65	Monkey, rhesus (M. mulatta)	♀7	3.6	0.03	2.57		0.34			1.89			0.01
66	Mouse, jumping (Zapus hudsonicus)	♂1♀3	0.018	0.04	3.57	0.14	1.03	1.26	5.63	1.34			0.01
67	Mouse, meadow (Microtus drummondi)	♂9♀7	0.023	0.05	2.09	0.10	0.68	1.53	4.56	1.70			0.01
68	Muskrat (Ondatra zibethica)	♂1	0.90	0.01	0.59	0.21	0.36	0.83	2.44	0.48		1.95	0.001
69	Opossum, woolly (Philander laniger)	♂1♀1	190	0.53			1.58	2.10	4.74	1.58	0.79		
70	Porcupine (Erethizon dorsatum)	♂1♀3	2.9	0.01	0.78	0.09	0.55	0.96	4	0.98			0.02
71	Porpoise (Phocaena phocaena)	♂1	140	0.007	1.22	0.04	0.52		2.08	3.69	0.04	9.28	0.01
72	Rabbit, giant Flemish (Lepus spp)	♂2	3.7	0.01	0.29		0.29	0.61	2.66				0.02
73	Rabbit, giant Flemish (Lepus spp)	♀22	2.5	0.02	0.40		0.35	0.70	3.19	0.53			
74	Raccoon (Procyon lotor)	♂1	5.2	0.02	0.82		0.81	0.68	3.58	3.58	0.28		
75	Raccoon (P. lotor)	♀1	2.2	0.07	1.51	0.15	0.89	1.61	6.29	0.87		10.11	0.008
76	Rat, Norway (Rattus norvegicus)	♂2♀1	0.25	0.05	1.22	0.10	0.52	1.09	3.35	0.79	0.29	2.52	0.001
77	Reedbuck (Redunca redunca)	♂2	31	0.006	0.34	0.10	0.76	0.32	1.65	1.34			0.004
78	Seal, ringed (Phoca hispida)	♂3♀2	39	0.007	0.63	0.18	0.73	0.70	2.81	1.85	0.32		0.008
79	Shrew (Blarina brevicauda)	♂29	0.02	0.02	1.87	0.009	1.02	1.08	5.81	2.24			0.01
80	Shrew (B. brevicauda)	♀39	0.017	0.02	2.11	0.006	1.05	1.25	5.45	2.19			0.01
81	Skunk (Mephitis mephitis)	♂1♀2	2.1	0.01	0.33		0.58	0.28	2.69	1.59			0.004

133. BODY AND ORGAN WEIGHTS: VERTEBRATES (Concluded)

Values are based on fresh weight for adult organs, determined immediately after death of the organism, and are grams/100 grams body weight.

	Species	Sex and Number	Body wt. kg	Adrenals g/100g	Brain g/100g	Eyes g/100g	Heart g/100g	Kidneys g/100g	Liver g/100g	Lungs g/100g	Spleen g/100g	Stomach & Intestines g/100g	Thyroid g/100g
						Mammalia (concluded)							
81	Sloth, three-toed(Bradypus tridactylus)	♂♀6	1.8	0.01	0.75								
82	Squirrel, red (Sciurus hudsonicus)	♂4	0.18	0.03	2.57	0.27	0.86	0.62	2.18	1.45			0.01
83	Squirrel, red (S. hudsonicus)	♀4	0.25	0.03	2.62	0.21	0.73	0.53	2.68	1.28			0.01
84	Steinbok (Raphicerus campestris)	♂2	8.6	0.01	0.57	0.17	0.84	0.45	2.03	1.74		4.38	0.01
85	Swine (Sus scrofa)	♀36	102	0.004			0.32	0.26	1.51		0.13	1.95	0.007
86	Tapir (Tapirella bairdii)	♂1;♀1	11.4	0.02			0.85	1.30	3.07	2.10	1.12		
87	Tiger (Panthera tigris)	♀1	160	0.01	0.14		0.27		1.14	0.64	0.57		
88	Walrus (Odobenus rosmarus)	♂1;♀3	600	0.002	0.17	0.003	0.68	0.68	2.92	1.36		4.42	0.01
89	Warthog (Phacochoerus aethiopicus)	♂1	65	0.01	0.19	0.03	0.50	0.46	2.30	0.84		15.23	0.005
90	Weasel, arctic (Mustela arctica)	♂3;♀1	0.18	0.01	2.80	0.08	1.71	0.99	4.74	2.08			0.05
91	Whale, white (Delphinapterus leucas)	♂4	447	0.006	0.52	0.007	0.55	0.49	1.52	2.70	0.04	2.70	0.02
92	Whale, white (D. leucas)	♀2	300	0.009	0.78	0.007	0.57	0.61	1.59	2.62	0.05	3.06	0.02
93	Wildebeest (Connochaetes taurinus)	♂2	210	0.003	0.21		0.62	0.23	1.07	1.34		17.54	0.005
94	Zebra (Equus burchelli)	♂1	32	0.01	0.52	0.08	1.08	0.82	2.76	3.56			
95	Zebra (Equus quagga)	♂3;♀1	280	0.008	0.20	0.03	1.42	0.35	1.67	0.80	0.41		0.007
						Aves							
96	Blackbird (Quiscalus quiscala)	♀1	0.08	0.02	3.56	0.23	0.14	0.16	3.21	0.21	0.06	7.78	0.01
97	Bluebird (Sialia sialis)	♂1;♀1	0.03	0.55	4.24		1.39						0.02
98	Buzzard, steppe (Buteo vulpinus)	♂1	0.56	0.05	1.41		0.82	0.60	1.94	0.83			0.03
99	Catbird (Dumetella carolinensis)	♀1	0.03	0.01	0.43		0.99			1.84			0.01
100	Canary (Serinus canarius)	♂1;♀1	0.016	0.04	4.72	1.75	1.29	0.16	5.39	0.15	0.11	14.17	0.008
101	Cowbird (Molothrus ater)	♀1	0.07	0.02	4.08		1.61						0.02
102	Crane, gray (Grus canadensis)	♂1	1.6	0.01	0.52	0.66	0.75	0.71	1.78	0.93	0.04	4.76	0.008
103	Crow (Corvus brachyrhynchos)	♂1	0.33	0.02	2.76		0.95			2.96			0.01
104	Duck, pintail (Anas acuta)	♀1	0.67	0.01	0.74	0.25	1.24	1.21	4.53	2.56	0.13	14.84	0.008
105	Eagle, tawny (Aquila rapax)	♂2;♀3	2.4	0.45	0.59	1.34	0.63	0.50	1.82	1.04		6.36	0.01
106	Egret, great white (Casmerodius albus)	♀1	1.0	0.02	0.59		0.90	0.79	3.20	3.21		13.11	0.01
107	Flamingo (Phoeniconaias minor)	♂3;♀2	1.5	0.02	0.49	0.22	0.94	1.18	2.68	1.47			0.03
108	Fowl, domestic (Gallus domesticus)	♂8	0.73	0.009	0.40	0.58	0.57	0.62	2.21	0.60	0.13		0.01
109	Fowl, domestic (G. domesticus)	♀16	0.61	0.01	0.44	0.58	0.63	0.68	2.36	0.61	0.15		0.01
110	Fowl, white leghorn, "germ-free"[1]	?	0.9-1.2	0.009			0.35		1.53	0.51			
111	Goose, Egyptian (Alopochen aegyptiacus)	♀1	1.9	0.02	0.39		0.96	0.50	1.77	1.80			0.02
112	Gunneafowl (Numida meleagris)	♂1	1.6	0.02	0.26		0.88	0.45	1.76	1.79			0.02
113	Gull, herring (Larus argentatus)	♀2	0.53	0.02	0.95	1.45	0.98		5.12				0.007
114	Hawk, red-tailed (Buteo borealis)	♀3	1.0	0.01	0.97	2.06	0.67	0.30	1.37	0.9		1.79	0.09
115	Hummingbird (Amazilia tzacatl)	♀1	0.005	0.007	4.16	2.50	2.37	0.81	5.23	0.20			0.009
116	Ostrich, masai (Struthio camelus)	♂1	125	0.02	0.03	0.08	0.98		1.66	2.36			
117	Owl, horned (Bubo virginianus)	♂1	1.2	0.01	1.16		0.73			0.91			0.007
118	Partridge (Francolinus sephaena)	♂1	0.21	0.02	0.72		0.70	1.30	4.16				0.009
119	Pelican (Pelecanus occidentalis)	♀2	3.3	0.01	0.54	0.38	0.67		2.22	0.91		7.75	0.005
120	Pheasant (Phasianus colchicus)	♂1	0.62	0.02	0.53	0.85	0.90	0.77	1.46			9.04	0.008
121	Pigeon (Columba livia)	♂3;♀1	0.27	0.16	0.95		1.75		1.76				0.11
122	Raven (Corvus corax)	♀1	1.25		2.81		0.85	0.71					0.009
123	Robin (Turdus migratorius)	♂2	0.07	0.03	3.01		1.46			2.42			0.01
124	Sparrow (Passer domesticus)	♂75	0.024	0.03	4.36	1.95	1.73	1.46	5.12	1.56	0.18	11.45	0.02
125	Sparrow (P. domesticus)	♀11	0.023	0.03	4.38	2.23	1.69	1.53	4.67	1.72	0.18	11.53	0.02
126	Starling (Sturnus vulgaris)	♂15	0.06	0.02	3.26	1.46	1.62	1.71	3.46	1.87	0.11	9.15	0.01
127	Starling (S. vulgaris)	♀10	0.06	0.02	3.13	1.80	1.49	1.85	3.76	1.87	0.07	9.69	0.01
128	Stork, European (Ciconia ciconia)	♂2;♀1	3.3	0.01	0.47	0.51	0.92	0.65	1.92	1.11			0.01
						Reptilia							
129	Alligator (Alligator mississipiensis)	♂2	190	0.004	0.007	0.01	0.15		0.38	0.54	0.07	2.95	0.006
130	Crocodile (Crocodylus acutus)	♂1;♀1	110	0.004	0.01		0.12		1.02	1.00			0.004
131	Iguana lizard (Iguana iguana)	♀1	1.3	0.02			0.19		2.49	0.28		3.18	0.009
132	Lizard (Lacerta viridis)	♂♀5	0.05	0.04	0.24		0.12	0.12	5		0.16		0.02
133	Snake, black (Coluber constrictor)	♂1;♀2	1.43	0.03	0.03	0.05	0.22	0.60	0.60	0.80	0.18	2.79	0.02
134	Snake, boa (Boa imperator)	♀1	1.8	0.008	0.02	0.03	0.31	0.52	1.66	0.76			0.008
135	Snake, green (Zamenis viridis)	♂3;♀3	0.022	0.36	0.95			8.77	2.19		0.57		0.20
136	Snake, python (Python molurus)	♀1	6.1	0.04	0.02	0.02	0.30						0.02
137	Snake, watermoccasin(Ancistrodon piscl)	♀1	0.73	0.14	0.09	0.08	0.65	1.85	8.85	3.12	0.76	41.24	0.07
138	Toad, horned (Phrynosoma cornutum)	♂2;♀3	0.025	0.03	0.52	1.28	0.44						
139	Turtle (Aromochelys triatycha)	♂1	0.12				0.43	0.43	2.8	0.85	0.18	2.729	
140	Turtle (A. triatycha)	♀2	0.09				0.48	0.47	2.9	0.76	0.17		
141	Turtle (Testudo graeca)	♂3;♀0	0.32	0.009	0.09			0.48	2.66		0.06		0.01
142	Turtle, cumberland (Chrysemys elegans)	♂21	0.84				0.32	0.32	5.43	1.07	0.22	6.23	
143	Turtle, cumberland (C. elegans)	♀1	0.86				0.31	0.36	5.92	0.84	0.47	7.32	
						Amphibia							
144	Frog, bull (Rana catesbiana)	♂7	0.49	0.02	0.93	0.48	0.32	0.29	2.75	0.53	0.07	4.72	0.007
145	Frog, leopard (R. pipiens)	♂10	0.036				0.43	0.43	2.81	0.85	0.18	3.50	
146	Frog, leopard (R. pipiens)	♀19	0.038				0.48	0.47	2.88	0.76	0.17	3.77	
						Pisces							
147	Barracuda (Sphyraena barracuda)	♂3;♀3	8.8		0.04	0.44	0.24	1.82	0.69		0.15	4.17	0.002
148	Carp (Cyprinus carpio)	♂2;♀4	1.05		0.12	0.28	0.15	0.55			0.22	3.7	0.0008
149	Codfish (Gadus morrhua)	♀1	10.6		0.05	0.6	0.15	0.19	1.52		0.95	5.47	0.006
150	Haddock (G. aeglefinus)	♀6	3.3		0.06	0.2	0.17	0.34	4.05		0.08	8.90	0.002
151	Mackerel (Scomber vernalis)	♂1	0.76		0.08								
152	Mackerel (S. vernalis)	♀2	1.5		0.11	0.54	0.20		0.43		0.12	0.20	0.002
153	Perch (Perca flavescens)	♂6	0.17		0.15	0.55	0.23	0.27	0.88		0.09	2.90	0.002
154	Perch (P. flavescens)	♀1	0.19		0.17	0.73	0.77		1.54			4.12	0.001
155	Pike (Esox lucius)	♂4;♀3	0.42		0.12	1.15	0.15	0.42	0.86		0.09	5.10	0.002
156	Salmon (Salmo salar)	♂3	3.4		0.03	0.23	0.36	1.05	2.02		0.32	6.29	0.005
157	Salmon (S. salar)	♀5	5.4		0.02	0.15	0.19	0.74	1.73		0.22	4.30	0.0007
158	Trout, rainbow (Salmo irideus)	♂2	0.26		0.17	0.69	0.17	0.55	0.99		0.21	9.58	0.003
159	Trout, rainbow (S. irideus)	♀4	0.22		0.19	0.70	0.13	0.50	0.99		0.27	8.89	0.002

/1/A discussion of the meaning of "germ-free" is given in the Lobund report of the University of Notre Dame.

	Species	Caught by Rod and Reel						Caught by Any Method			
		Weight		Length	Girth	Location	Date	Weight		Location
		lb	oz	in.	in.			lb	oz	
	Fresh-water Records[1]									
1	Black bass, largemouth (Micropterus salmoides)	22	4	32½	28½	Montgomery Lake, Ga.	1932	Same		
2	Black bass, smallmouth (M. dolomieu)	10	8	22½	21½	Wheeler Dam, Ala.	1950	Same		
3	Bluegill sunfish (Lepomis macrochirus)	4	12	15	18½	Ketona Lake, Ala.	1950	Same		
4	Bullhead, black (Ameiurus melas)	8		24	17½	Lake Waccabuc, N. Y.	1951	Same		
5	Carp (Cyprinus carpio)	55	5	42	31	Clearwater Lake, Minn.	1952	83	8	Pretoria, S. Africa
6	Catfish, blue (Ictalurus furcatus)	94	8	56	35	James River, S. D.	1949	Same		
7	Catfish, channel (I. lacustris)	55		50	27	James River, S. D.	1949	Same		
8	Charr, arctic (Salvelinus alpinus)	11	8	30	17	Richmond Gulf, Hud. Bay	1950	Same		
9	Gar, alligator (Lepisosteus spatula)	279		93		Rio Grande River, Tex.	1951	Same		
10	Muskellunge (Esox masquinongy)	69	11	63½	31½	Chippewa Flowage, Wis.	1949	102		Minocqua Lake, Wis.
11	Perch, white (Morone americana)	4	12	19½	13	Messalonskee Lake, Me.	1949	Same		
12	Perch, yellow (Perca flavescens)	4	3½			Hordentown, N. J.	1865	Same		
13	Pickerel, eastern chain (Esox niger)	9		30	15	Green Pond, N. J.	1948	9	5	Pontooeuc Lake, Mass.
14	Pike, northern (E. lucius)	46	2	52½	25	Sacandaga Res., N. Y.	1940	Same		
15	Pike, walleyed (Stizostedion vitreum)	22	4	36½	21	Fort Erie, Ontario	1943	Same		
16	Salmon, Atlantic (Salmo salar)	79	2			Tanselv, Norway	1928	103	2	River Devon, Scotland
17	Salmon, chinook (Oncorhynchus tschawytscha)	83				Umpqua River, Ore.	1910	126	8	Petersburg, Alaska
18	Salmon, landlocked (Salmo sebago)	22	8	36		Sebago Lake, Me.	1907	35		Crooked River, Me.
19	Salmon, silver (Oncorhynchus kisutch)	31				Cowichan Bay, B. C.	1947	Same		
20	Trout, brook (Salvelinus fontinalis)	14	8			Nipigon River, Ontario	1916	Same		
21	Trout, brown (Salmo trutta)	39	8			Loch Awe, Scotland	1866	40		Grest Lake, Tasmania
22	Trout, cut-throat (S. clarkii)	41		39		Pyramid Lake, Nev.	1925	Same		
23	Trout, Dolly Varden (Salvelinus malma)	32		40½	29½	L. Pend Oreille, Id.	1949	Same		
24	Trout, golden (Salmo agua-bonita)	11		28	16	Cook's Lake, Wyo.	1948	Same		
25	Trout, lake (Cristivomer namaycush)	63	2	51½	32½	Lake Superior	1952	80		Mackinaw, Mich.
26	Trout, rainbow[2] (Salmo gairdneri)	37		40½	28	Lake Pend Oreille, Id.	1947	42		Corbett, Ore.
27	Trout, Sunapee (Salvelinus aureolus)	11	8	33	17½	Lake Sunapee, N. H.	1954	Same		
	Salt-water Records[3]									
28	Albacore (Thunnus germo)	66	4			Catalina, Calif.	1912	Same		
29	Amberjack (Seriola lalandi)	119	8	63½	46½	Rio de Janeiro, Brazil	1952	146		Flatts Inlet, Bermuda
30	Barracuda (Sphyraena barracuda)	103	4	66	31½	West End, Bahamas	1932	Same		
31	Bass, Calif. white sea (Cynoscion nobilis)	83	12	65½	34	Baja, Mexico	1953	Same		
32	Bass, channel (Sciaenops ocellata)	83		52	29	Cape Charles, Va.	1949	Same		
33	Bass, giant black sea (Stereolepis gigas)	483		87	73	Coronado Is., Mexico	1951	800		Avalon, Calif.
34	Bass, giant sea (Promicrops itaiara)	551		100.		Galveston Bay, Tex.	1937	Same		
35	Bass, sea (Centropristes striatus)	8		22	19	Nantucket Sound, Mass.	1951	Same		
36	Bass, striped (Roccus saxatilis)	73		60	30½	Vineyard Sound, Mass.	1913	125		Edenton, N. C.
37	Blackfish (Tautoga onitis)	21	6	31½	23½	Cape May, N. J.	1954	22	8	Near New York
38	Bluefish (Pomatomus saltatrix)	24	3	41	22	San Miguel, Azores	1953	27		Nantucket, Mass.
39	Bonefish (Albula vulpes)	18	2	41½	18	Mana, Kauai, T. H.	1954	Same		
40	Bonito, oceanic (Katsuwonus pelamis)	39	15	39	28	Walker Cay, Bahamas	1952	Same		
41	Cobia (Rachycentron canadus)	102		70	34	Cape Charles, Va.	1938	Same		
42	Cod (Gadus callarias)	57	8	56		Ambrose Lightship, N. Y.	1949	Same		
43	Dolphin (Coryphaena hippurus)	75	8	50	21	Mafia Channel, E. Africa	1950	Same		
44	Drum, black (Pogonias cromis)	88		48		Delaware Bay, N. J.	1954	146		St. Augustine, Fla.
45	Flounder, summer[4] (Paralichthys dentatus)	20		37	32	Oak Beach, N. Y.	1948	26		Noank, Conn.
46	Kingfish[5] (Scomberomorus cavalla)	76	8	63	31	Bimini, Bahamas	1952	100		
47	Marlin, blue (Makaira nigricans ampla)	742		154½	68	Bimini, Bahamas	1949	1200		Havana, Cuba
48	Marlin, Pacific black (M. nigricans marlina)	1560		174	81	Cabo Blanco, Peru	1953	Same		
49	Marlin, silver (M. nigricans tahitiensis)	755		163½	65½	Pinas Bay, Panama	1953	Same		
50	Marlin, striped (M. mitsukurii)	692		161		Balboa, Calif.	1931	Same		
51	Marlin, white (M. albida)	161		104	33	Miami Beach, Fla.	1938	Same		
52	Pernit (Trachinotus goodei)	42	4	43	33½	Boca Grunge, Fla.	1953	Same		
53	Pollack (Pollachius virens)	32	4	44	26½	Belmar, N. J.	1953	Same		
54	Roosterfish (Nematistius pectoralis)	100		54	32	Cabo Blanco, Peru	1954	Same		
55	Sailfish, Atlantic (Istiophorus americanus)	123		124	32½	Walker Cay, Bahamas	1950	Same		
56	Sailfish, Pacific (I. greyi)	221		129		Galapagos Islands	1947	Same		
57	Sawfish (Pristis pectinatus)	736		175		Galveston, Tex.	1938	1500		Aransas Pass, Tex.
58	Shark, mako, Atlantic (Isurus oxyrhynchus)	1000		144		Mayor Island, N. Z.	1943	Same		
59	Shark, man-eater[6] (Carcharodon carcharias)	2372		181	117	Streaky Bay, Australia	1953	Same		
60	Shark, porbeagle (Lamna nasus)	260		136	68½	Durban, S. Africa	1949	Same		
61	Shark, thresher (Alopias vulpinus)	922				Bay of Islands, N. Z.	1937	Same		
62	Shark, tiger (Galeocerdo cuvier)	1382		166	93	Sydney Heads, Australia	1939	Same		
63	Snook[7] (Centropomus undecimalis)	50	8	55		Gatun Spillway, C. Z.	1944	Same		
64	Swordfish (Xiphias gladius)	1182		179	78	Iquique, Chile	1953	Same		
65	Tarpon (Tarpon atlanticus)	247		89½		Panuco River, Mexico	1938	350		Hillsboro River, Fla.
66	Tuna, Allison[8] (Thunnus albacares)	265		73	53	Makua, T. H.	1937	Same		
67	Tuna, big-eyed (Parathunnus sibi)	368		89	63½	Cabo Blanco, Peru	1953	Same		
68	Tuna, bluefin (Thunnus thynnus)	977		116	94½	St. Ann Bay, N. S.	1950	1800		Wedgeport, Nova Sco.
69	Tuna, dog-toothed (Gymnosarda nuda)	151	8			Tahiti	1936	Same		
70	Wahoo (Acanthocybium solandri)	133	8	83	31	Green Cay, Bahamas	1943	Same		
71	Weakfish (Cynoscion regalis)	17	8	46	19	Mullica River, N. J.	1944	30		New Jersey
72	Weakfish, spotted (C. nebulosus)	15	3	34½	20½	Fort Pierce, Fla.	1949	15	4	Indian River, Fla.
73	Yellowtail (Seriola dorsalis)	90		59	35½	La Paz, Mexico	1948	Same		

/1/ Compiled by Field and Stream magazine. /2/ Or steelhead. /3/ Compiled by International Game Fish Association. /4/ Northern fluke. /5/ Or king mackerel. /6/ Or white shark. /7/ Robalo. /8/ Or yellowfin.

Except where otherwise indicated, values are as follows: those for larvae are for the last instar; averages for both sexes are in milligrams; and ranges in parenthesis conform with estimate "c" of the 95% range (cf Introduction).

	Species	Fresh Weight			Dry Weight		
		Larva mg	Pupa mg	Adult mg	Larva mg	Pupa mg	Adult mg
	ORTHOPTERA						
1	Cockroach, American (Periplaneta americana)			♂890(550-1470); ♀1050(650-1720)			
2	Cockroach, giant (Micropanesthia rhinoceria)			19.3g (18.4-19.5g)			
3	Cockroach, German (Blattella germanica)			♂(39-45); ♀(70-73)			
4	Cockroach, Hawaiian (Nyctobora noctivaga)			(1290-2190)			
5	Cockroach, Oriental (Blatta orientalis)			♂400(323-515)[1,2] ♀750(540-870)[1,2]			♂100(81-126)[1]; ♀205(147-237)[1]
6	Grasshopper, differential (Melanoplus differentialis)			♂854(436-1232); ♀1428(812-2607)			
7	Grasshopper, Rocky Mt. (M. mexicanus mexicanus)			♂(153-161)[3]; ♀(156-165)[3]			
8	Locust, migratory (Locusta migratoria)	(372-578)[4]		♂1350(1205-1400); ♀2500(2250-2900)[5]	119-183[6]		♂565[7]; ♀1212[8,9]
9	Walking stick (Dixippus morosus)			1050(900-1100)			
10	Walking stick (Sipodromantis hioculata)			2079			
	ODONATA						
11	Fly, big green dragon (Anax junius)	(1200-1500)		(500-900)			
	ANOPLURA						
12	Louse, bloodsucking (Enderleinellus zonatus)			♂0.00[10]			
	HEMIPTERA						
13	Bug, bordder (Leptocoris trivittatus)			(32-39)[3]			(10.5-10.6)[3]
14	Bug, milkweed, large (Oncopeltus fasciatus)			♂47(31-75); ♀66(40-95)			
	LEPIDOPTERA						
15	Cabbageworm, imported (Pieris rapae)	156(110-165)					
16	Hornworm, tomato (Protoparce quinquemaculata)	6.3g (6.2-10.5g)					
17	Moth, bee (Galleria mellonella)	175(85-310)			64(30-110)		
18	Moth, codling (Carpocapsa pomonella)	47(42-63)					
19	Moth, ratain (Ephestia figullilella)	19.4					
20	Moth, striped sphinx (Deilephila euphorbiae)	4036	2609	1263	848	652	401
21	Moth, webbing clothes (Tineola bisellielia)	(6.5-9.2)[11]	(3.0-5.5)[11]	♂(2.1-4.3); ♀(4.1-9.4)[11]			
22	Silkworm (Bombyx mori)	1770[12]	1170		374	339	
	DIPTERA						
23	Fly, black blow (Phormia regina)	44(22-63)		♂(38-40)[3]; ♀(42-50)[3]	9(5-13)		
24	Fly, black cherry fruit (Rhagoletis fausta)			♂3.0(1.8-3.9)[13]; ♀4.1(1.5-6.8)[b]			
25	Fly, bluebottle (Calliphora erythrocephala)			♂(50-69)[3]; ♀(60-77)[3]			
26	Fly, giant crane (Tipula abdominalis)	1200(800-1600)					
27	Fly, greenbottle (Lucilia sericata)	0.05[13]	28(24-35)	♂27; ♀40			
28	Fly, house (Musca domestica)		(22-27)[14]	♂(12-17); ♀(16-21)			
29	Maggot, apple (Rhagoletis pomonella)			♂4.6(2.6-7.5)[13]; ♀6.9(1.7-11)[b]			
30	Maggot, cherry (R. cingulata)			♂3.8(2.4-5.2)[13]; ♀5.1(3.2-7.0)[b]			
31	Mosquito (Culex tarsalis)		2.2				
32	Mosquito, malaria (Anopheles quadrimaculatus)	1.91	♂2.99; ♀3.45	♂1.37; ♀1.66[15] (3.6-3.9)[16]	0.61	♂0.60; ♀0.69	♂0.39; ♀0.47
33	Mosquito, yellow-fever (Aedes aegypti)						
	COLEOPTERA						
34	Beetle, Colorado potato (Leptinotarsa decemlinesta)	98(83-110)[17]		♂160(146-176); ♀173			53
35	Beetle, confused-flour (Tribolium confusum)	2.0(1.5-2.4)		2.1(1.4-3.5)[18]			0.7(0.6-0.8)[19]
36	Beetle, convergent lady (Hippodamia convergens)			21.3			10.4
37	Beetle, diving (Dysticus marginalis)	1366(1305-1498)	1950	1356(1186-1466)			
38	Beetle, goliath (Goliathus goliathus)[20]			(40-100g)[21]			(15-35g)
39	Beetle, Japanese (Popillia japonica)	(196-276)	(176-222)[3]	♂114; ♀146	(44-60)[3]	(42-52)[3]	♂38; ♀49
40	Beetle, lady (Ceratomegilla fusciabrus)			13.1			5.4
41	Mealworm, yellow (Tenebrio molitor)	(83-180)[22]					33(22-46)
42	Weevil, bean (Acanthoscelides obtectus)			♂(2.9-6.8); ♀(2.8-8.3)			
	HYMENOPTERA						
43	Ant, giant (Camponotus gigas)			(75-342)			
44	Bee, honey, worker (Apis mellifera)	137(158-171)	150(147-176)	120(87-134)[23]		35(34-41)	(16-18.6)[3]
45	Wasp, paper-nest (Polistes variatus), queen			149			59
46	Wasp, parasitic (Carpbractus cinctus)			0.005[10,24]			

/1/ Five da adult. /2/ 60-70 da, ♀1036(833-1165); 120 da, ♀914(781-1200). /3/ Averages from different experiments. /4/ At fifth instar; first instar, 14.3; second, 33.2-37.6; third, 66.4-77.4; fourth, 164-221. /5/ Ons da, ♀960-1900. /6/ At fifth instar; first instar, 3.12; second, 6.2-7.3; third, 16.2-26.6; fourth, 41.5-83.4. /7/ One da, ♂202-233. /8/ One da, ♀284-346. Values in Footnotes 4-8 are averages from different phases and reaging conditions. /9/ Weight prior to laying eggs. /10/ Smallest known insects; weights are approximate calculations from published measurements. /11/ Smaller if reared at 30°C; larger at 20°C. /12/ Other values, 3500; Italian strain, 4100; Japanese strain, 8417. /13/ Value for one hr larvae; 24 hr, 1.5(1-2); 48 hr, 17.8(16-20); 72 hr, 52(45-57); 96 hr, 52(43-56); 144 hr, 42(39-44). /14/ Also reported as (16-24.3); densely crowded cultures give pupae as small as 4 mg. /15/ Unfed ♀. /16/ Unfed, 1.5-1.75. /17/ Age not stated; probably only partly grown. /18/ One da adult, fresh weight 1.75(1.5-2.0). /19/ One da adult. /20/ Heaviest known insect. /21/ Calculated from dry weight of museum specimens corrected for recorded measurements. /22/ From hatching to largest fully grown larvae, 1-200. /23/ Queen, 262. /24/ Egg, 0.0002.

Part I: AGES OF TOOTH DEVELOPMENT AND ERUPTION: MAN

Values are approximate averages for whites without regard to sex. F = fetal age; P = postnatal age.

	Teeth	Appearance of Tooth Bud		Beginning of Calcification	
		Deciduous	Permanent	Deciduous	Permanent
		mo	mo	mo	mo
1	Incisors, first	F 3	F 6	F 5	P 3, 5
2	second	F 3	F 6	F 5	P 3, 5, 12[1]
3	Canines	F 3	F 6	F 6	P 4, 5
4	Premolars, first		P 10		P 21
5	second		P 18		P 30
6	Molars, first	F 3	F 5	F 5	Birth
7	second	F 3	P 6	F 6	P 33
8	third		P 60		P 7-10 yr

	Teeth	Emergence into Oral Cavity		Root Completion	
		Deciduous	Permanent	Deciduous	Permanent
		mo	yr	yr	yr
9	Incisors, first	PT7(9.4)-14	P 6, 7[1]	P 1.5-2	P 9-10
10	second	P 12	P 8	P 1.5-2	P 10-11
11	Canines	P 20	P 10, 11[1]	P 2. 5-3	P 12-15
12	Premolars, first		P 10		P 12-13
13	second		P 11		P 12-14
14	Molars, first	P 16	P 6	P 2-2. 5	P 9-10
15	second	P 27[2]	P 12	P 3	P 14-16
16	third		P 20. 5		P 18-25

/1/ First value mandibular, second value maxillary tooth. /2/ 4-12 mo = 98% range; 0-16 mo = extreme range. Prenatal emergence occurs rarely. /3/ 18-36 mo = 98% range; 10-38 mo = extreme range.

Part II: AGES OF DECIDUOUS TOOTH ERUPTION: MAMMALS

Values are days. Ranges in parentheses, conforming to estimate "b" or "c" of the 95% range (cf Introduction), are noted by superscript. MX = maxillary; MD = mandibular.

	Animals		Incisors			Canines	Molars		
			First	Second	Third		First	Second	Third
1	Man	♂ MX	277(187-367)[b]	316(173-459)[b]		575(414-736)[b]	486(349-623)[b]	839(576-1102)[b]	
2		♀ MX	222(126-318)[b]	395(228-562)[b]		587(415-759)[b]	492(378-606)[b]	787(560-1014)[b]	
3		♂ MD	252(172-332)[b]	356(201-523)[b]		611(421-801)[b]	477(340-614)[b]	863(606-1120)[b]	
4		♀ MD	237(112-362)[b]	420(206-634)[b]		614(412-816)[b]	474(343-605)[b]	824(573-1075)[b]	
5	Cattle[1]	MX					(0-14)[c]	(0-10)[c]	(0-10)[c]
6		MD	(0-7)[2]	(0-14)[2]	(0-21)[2]	(14-42)[3]	(0-14)[2]	(0-10)[2]	(0-10)[2]
7	Chimpanzee[4]	♂ MX	111(77-161)[c]	122(83-177)[c]		355(266-411)[c]	226(77-380)[c]	308(226-446)[c]	
8		MD	95(55-126)[c]	124(68-188)[c]		376(293-459)[c]	150(79-210)[c]	247(183-338)[c]	
9		♀ MX	76(40-108)[c]	94(74-112)[c]		327(226-445)[c]	111(74-152)[c]	225(153-379)[c]	
10		MD	70(53-83)[c]	88(65-112)[c]		351(265-492)[c]	135(106-176)[c]	225(154-291)[c]	
11	Dog[1]	MX	(21-42)	(21-42)	(28-42)	(21-28)	(28-35)	(21-35)	(21-28)
12		MD	(21-42)	(21-42)	(28-42)	(21-28)	(28-35)	(21-35)	(21-28)
13	Horse[1]	MX	(0-14)[2]	(14-42)	(150-270)	Vestigia[5]	(0-14)[2]	(0-14)[2]	(0-14)[2]
14		MD	(0-14)[2]	(14-42)	(150-270)	Vestigia[5]	(0-14)[2]	(0-14)[2]	(0-14)[2]
15	Monkey, rhesus	♂ MX	19.1(-0.39-39)[b]	39(15-63)[b]		68(41-95)[b]	73(49-97)[b]	164(117-211)[b]	
16		MD	15.2(-3.86-34)[b]	23(1-45)[b]		71(44-98)[b]	78(54-102)[b]	152(115-189)[b]	
17		♀ MX	19.5(0.7-38)[b]	38(14-62)[b]		71(44-98)[b]	68(41-95)[b]	155(110-200)[b]	
18		MD	16(-0.5-32)[b]	23(3-43)[b]		73(42-104)[b]	73(48-98)[b]	139(102-176)[b]	
19	Orangutan[7]	♂ MX	147	229		343	169	303	
20		MD	134	204		345	162	283	
21	Pig[1]	MX	(14-28)	(60-90)	Prenatal	Prenatal	(35-49)	(4-8)	(4-8)
22		MD	(14-28)	(45-60)	Prenatal	Prenatal	(35-49)	(14-8)	(14-28)

/1/ Values vary with breed. /2/ Lower limit of emergence prenatal in many animals. /3/ Fourth incisor. /4/ Similar values for lowland gorilla (Gorilla gorilla) with possible exception that canines may precede second molars. /5/ Vestigial teeth; do not erupt. /6/ Prenatal eruption. /7/ Values from single animal.

Part III: AGES OF PERMANENT TOOTH ERUPTION: MAMMALS

Values are years unless otherwise indicated. Ranges in parentheses for white male and female are estimate "b," and for monkey estimate "c," of the 95% range (cf Introduction). MX = maxillary; MD = mandibular.

	Animals		Incisors			Canines	Premolars				Molars		
			First	Second	Third		First	Second	Third	Fourth	First	Second	Third
1	Man, white,	MX	7.47(5.88-9.06)	8.67(6.75-10.59)		11.69(9.0-14.38)	10.40(7.52-13.28)	11.18(8.1-14.26)			6.40(4.83-7.97)	12.68(9.99-15.37)	20.5(16-27)[1]
2	male	MD	6.54(5.01-8.07)	7.70(5.98-9.42)		10.79(8.3-13.28)	10.82(7.88-13.7)	11.45(8.14-14.76)			6.21(4.64-7.78)	12.25(9.45-14.79)	20.5(16-27)[1]
3	female	MX	7.20(5.61-8.79)	8.20(6.28-10.12)		10.98(8.29-13.67)	10.03(7.15-12.91)	10.88(7.8-13.96)			6.22(4.65-7.79)	12.27(9.58-14.96)	20.5(16-27)[1]
4	Negro[2]	MD	6.26(4.73-7.79)	7.34(5.62-9.06)		9.86(7.37-12.35)	10.18(7.3-13.06)	10.89(7.6-14.18)			5.94(4.37-7.51)	11.66(8.99-14.33)	20.5(16-27)[1]
5		MX	6.0(5.0-8.0)	7.5(5.0-8.0)		10.3(8.0-13.0)	10.0(8.0-12.0)	10.3(8.0-12.0)			6.0(5.0-8.0)	11.5(9.0-13.0)	19.0(12-?)
6		MD	5.5(5.0-7.0)	6.5(5.0-8.0)		10.0(6.0-13.0)	10.0(8.0-13.0)	10.3(8.0-13.0)			5.5(5.0-8.0)	11.5(9.0-14.0)	18.0(12-?)
7	Cattle[3]	MX				(2.0-2.5)	(1.5-2.5)	(2.5-3.0)			(0.4-0.7)	(1.0-1.5)	(2.0-2.5)
8		MD	(1.5-2.0)	(2.0-2.5)	(2.8-3.3)	(2.5-4.0)[4]	(2.0-2.5)	(1.5-2.5)	(2.5-3.0)		(0.4-0.7)	(1.0-2.5)	(2.0-2.5)
9	Chimpanzee[5]	MX	5.4(4.8-6.0)	5.8(5.3-6.2)		7.2(6.8-7.5)	6.2(5.8-6.6)	6.6(6.0-7.2)			2.9(2.8-3.0)	6.4(6.1-6.8)	10.3(9.8-11.2)
10		MD	5.2(4.8-5.8)	5.5(5.4-6.1)		7.5(7.0-8.3)	6.0(4.8-6.7)	6.5(6.1-7.0)			2.9(2.8-3.0)	6.3(6.1-6.6)	9.3(8.7-10.1)
11	Dog[3]	MX	(0.2-0.4)	(0.2-0.5)	(0.2-0.4)	(0.3-0.5)	(0.3-0.5)	(0.4-0.5)		(0.4-0.5)	(0.4-0.5)	(0.3-0.5)	(4.0-5.0)
12		MD	(0.2-0.4)	(0.2-0.4)	(0.3-0.5)	(0.3-0.5)	(0.3-0.5)	(0.4-0.5)		(0.4-0.5)	(0.4-0.5)	(0.3-0.5)	(0.5-0.6)
13	Goat	MX				(1.0-1.3)	(1.0-1.3)	(1.0-1.3)			(1.7-1.8)	20 da	(0.8-0.9)
14		MD	(1.0-1.3)	(1.7-1.8)	(2.7-3.0)	(3.5-4.0)[4]	(1.0-1.3)	(1.0-1.3)			(1.7-1.8)	20 da	(0.8-0.9)
15	Hamster,	MX	(0-2) da								(7-9) da	(13-14) da	(32-36) da
16	golden	MD	(0-2) da								(7-8) da	(12-13) da	(29-32) da
17	Horse[3]	MX	(2.2-3.0)	(3.5-4.0)	(4.2-5.0)	(3.5-5.0)[6]	(0.4-0.5)[7]	(2.0-2.5)			(0.3-0.5)	(0.4-0.5)	(1.5-2.0)
18		MD	(2.2-3.0)	(3.5-4.0)	(4.2-5.0)	(3.5-5.0)	(0.4-0.5)[7]	(2.0-2.5)			(2.5-3.0)	(3.5-4.0)	(0.5-1.0)
19	Monkey,	MX	2.7(2.1-3.0)	3.2(3.1-3.4)		4.3(3.8-5.4)	3.9(3.5-4.8)	4.0(3.6-4.7)				1.5(1.2-1.9)	3.6(3.2-4.0)
20	rhesus	MD	2.8(2.2-3.0)	3.0(2.7-3.4)		4.2(3.7-5.1)	4.2(3.7-5.1)	4.1(3.6-4.9)				1.3(1.0-1.9)	3.5(3.2-4.2)
21	Mouse, albino	MX	10 da									15 da	(15-20) da
22		MD	10 da									15 da	(15-20) da
23	Pig[3]	MX	1.0	(1.3-1.7)	(0.7-0.8)	(0.7-0.8)	0.4	(1.0-1.3)	(1.0-1.3)	(1.0-1.3)	(0.3-0.5)	(0.7-1.0)	(1.5-1.7)
24		MD	1.0	(1.3-1.7)	(0.7-0.8)	(0.7-0.8)	0.4	(1.0-1.3)	(1.0-1.3)	(1.0-1.3)	(0.3-0.5)	(0.7-1.0)	(1.5-1.7)
25	Rat, albino	MX	(8-10) da								20 da	(22-23) da	(31-36) da
26		MD	(8-10) da								19 da	(21-22) da	(29-35) da
27	cotton	MX	Prenatal-1.0 da								(5-7) da	(9-13) da	(28-33) da
28		MD	Prenatal								(4-7) da	(7-12) da	(26-30) da
29	Sheep	MX				(1.5-2.0)	(1.5-2.0)	(1.5-2.0)			0.4	(0.7-1.0)	(1.5-2.0)
30		MD	(1.0-1.5)	(1.5-2.0)	(2.5-3.0)	(3.5-4.0)[4]	(1.5-2.0)	(1.5-2.0)	(1.5-2.0)		0.3	(0.7-1.0)	(1.5-2.0)

/1/ Eruption at 13 years rare; somewhat less exceptional at ages 14 and 15. /2/ African Zulus. /3/ Values vary with breed. /4/ Fourth incisor. /5/ Values derived from 3-6 animals of closely estimated ages. Gorilla data available only for individuals captured at very early age; values are approximately the same as for the chimpanzee. /6/ Usually absent in mares. /7/ Rarely erupts.

Dist. = distally; extr. = extremities; f. = fused; innom. = innominate; pn. = prenasal;

	Bone	Monotremata		Marsupialia	Insectivora	Chiroptera	Primates					
		Platypus, duckbilled (Platypus ornithorhynchus)	Anteater, spiny (Tachyglossus spp)	Opossum, Virginia (Didelphis virginiana)	Shrew, common (Sorex personatus)	Bat, big brown (Eptesicus fuscus)	Lemur (Lemur macaco)	Monkey, New World "Howler" (Alouatta beelzebul)	Monkey, Old World (Colobus polykomos)	Chimpanzee (Pan troglodytes)	Man (Homo sapiens)
	Skull										
1	Occipital (chondral)	1	1	1	1	1	1	1	1	1	1
2	Parietal (dermal)	1 pr., f.	1 pr., f.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr.
3	Sphenoid[2]										1
4	Ethmoid (chondral)	1	1	1	1	1	1	1	1	1	1
5	Turbinal (chondral)	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	1 pr.
6	Interparietal (dermal)	0	0	0	0	0	0	0	0	0	0
7	Frontal (dermal)	1 pr., f.	1 pr., f.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.
8	Nasal (dermal)	1 pr., 1 pn.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr.
9	Lacrimal (dermal) [3]	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
10	Temporal, periotic [3] (petrosal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	} f.	} f.	} f.	} f.	} f.
11	Temporal, tympanic	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.					
12	Temporal, squamosal (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.					
13	Premaxilla (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	0	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.
14	Maxilla (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
15	Jugal (zygomatic, or malar; dermal)	1 pr.	1 pr.	1 pr.	0	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	
16	Vomer (chondral)	1	1	1	1	1	1	1	1	1	1 pr.
17	Palatine (dermal)	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
18	Mandible (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.
19	Hyoid, basi- (splanchnic)	1	1	1	1	1	1	1	1	1	1
20	Hyoid, stylo- (splanchnic)	0	0	0	1 pr.	1 pr.	1 pr.	0	0	0	0
21	Hyoid, epi- (splanchnic)	1 pr.	0	0	1 pr.	1 pr.	1 pr.	0	0	0	0
22	Hyoid, cerato- (splanchnic)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	0	1 pr.
23	Hyoid, thyro- (splanchnic)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
	Vertebrae										
24	Cervical	7	7	7	7	7	7	7	7	7	7
25	Thoracic	17	16	13	13	11-12	12	12-13	12-13	13	12
26	Lumbar	2	3	6	6	5-6	6	6	6	4	5
27	Sacral	2	3-4	2		3	3	3	3	4-5	5, f.
28	Caudal	20-23	12-13	19-35		9a	25-29	27a	23a	4-5	4
	Vertebral Ribs										
29	Ribs, "true"	6 pr.	6 pr.	7 pr.	} 13 pr.	7 pr.	7 pr.	5 pr.	7 pr.	7 pr.	7 pr.
30	Ribs, "false"	11 pr.	10 pr.	6 pr.		4 pr.	5 pr.	7-8 pr.	5-6 pr.	6 pr.	5 pr.
	Sternum										
31	Manubrium	1	1	1	1	1	1	1	1	1	1
32	Sternebrae	5	5, f.	4	5	1	4	4	4	1	1
33	Xiphisternum	0	1	1	1	1, f.	1	1	1	1	1
34	Ribs, sternal	6 pr.	6 pr.	7 pr.		7 pr.					
	Pectoral Girdle										
35	Interclavicle	1	1	0	0	0	0	0	0	0	0
36	Coracoid	1 pr.	1 pr.	*	*	*	*	*	*	*	*
37	Coracoid, anterior	1 pr.	0 pr.	0	0	0	0	0	0	0	0
38	Clavicle	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
39	Scapula	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
	Upper Extremity										
40	Humerus	1	1	1	1	1	1	1	1	1	1
41	Radius	1	1	1	1	1	1	1	1	1	1
42	Ulna	1	1	1	1	* or 0	1	1	1	1	1
43	Carpus										
44	Scaphoid	} 1	} 1	1	1	} 1	1	1	1	1	1
45	Lunate			1	1		1	1	1	1	1
46	Cunelform [3] (triquetral)	1	1	1	1	1	1	1	1	1	1
47	Pisiform	1	1	1	1	1	1	1	1	1	1
48	Centrale	0	0	0	0	0	0	1	1	0	0
49	Trapezium	1	1	1	1	1	1	1	1	1	1
50	Trapezoid	1	1	1	1	1	1	1	1	1	1
51	Magnum [3] (capitate)	1	1	1	1	1	1	1	1	1	1
52	Unciform [3] (hamate)	1	1	1	1	1	1	1	1	1	1
53	Metacarpus	5	5	5	5	5	5	5	5	5	5
54	First										
55	Second										
56	Third										
57	Fourth										
58	Fifth										
	Phalanges										
59	First digit	2	2	2	2	2	2	2	2	2	2
60	Second digit	3	3	3	3	2	3	3	3	3	3
61	Third digit	3	3	3	3	3	3	3	3	3	3
62	Fourth digit	3	3	3	3	2	3	3	3	3	3
63	Fifth digit	3	3	3	3	2	3	3	3	3	3

/1/ The order Edentata is so diversified that all skeletal modifications cannot be included. /2/ In most mammals the sphenoid element is formed anatomy; alternate name, used in human anatomy (Nomina Anatomica, 1955), is in parentheses. /4/ Fused with sphenoid. /5/ Ossified

MAMMALS

pr. = pair; prox. = proximally; sph. = sphenoid; var. = variable; * = rudimentary bone.

	Carnivora			Ungulata			Pro-bocidea	Sirenia	Cetacea		Edentata[1]	Rodentia		Lago-morpha	
	Cat, domestic (Felis domesticus)	Dog (Canis familiaris)	Seal, harbor (Phoca vitulina)	Horse (Equus caballus)	Cattle, domestic (Bos taurus)	Swine (Sus scrofa)	Elephant, Asiatic (Elephas maximus)	Manatee (Trichechus spp)	Porpoises, harbor (Phocaena phocaena)	Whale, finback (Balaenoptera physalus)	Armadillo, nine-banded (Dasypus novemcinctus)	Guinea pig (Cavia cobaya)	Rat, Norway (Rattus norvegicus)	Hare, varying (Lepus americanus virginianus)	
Skull															
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1
															2
															3
	1		1	1		1	1	1	1	1	1	1	1	1	4
	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	1+ pr.*	1 pr	0	*	2 pr.	2 pr.	2 pr.	2 pr.	5
	1	1	1	0	0	0	0	0	1	0	1	0	1	0	6
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	7
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0 or *	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	8
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	*	0	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	9
					1 pr.	1 pr.				1 pr.					10
	f.	f.	f.	f.	f.	f.	1 pr.	1 pr.	1 pr.	f.	f.	f.	1 pr.	1 pr.	11
				1 pr.		1 pr.						1 pr.		1 pr.	12
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	13
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	14
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	15
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	16
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0[4]	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	17
	1 pr.	1 pr.	1 pr., f.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	18
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	0	0	20
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	0	0	0	1 pr.	0	0	0	21
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	0	0	0	1 pr.	1 pr.	0	0	22
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	23
Vertebrae															
	7	7	7	7	7	7	7	6	7, f.	7, f.	7, f.	7, 2 & 3 f.	7	7	24
	13	13	14–15	18–19	13–14	14–15	19–20	17–18	13	14	10	5–13	13	12	25
	7	7	5	6	6	5–7	3–4	2	17	15	4–5	5–6	6–7	7	26
	2–3	3	4–5	5	5	4	4	1*	0	0	7	2	3–4	2–3	27
	18*	var.	9–14	15–21	16–21	20–26	31*	25*	25*	24*	27*	8*	27*	var.	28
Vertebral Ribs															
	9 pr.	9 pr.	10 pr.	8 pr.	7–8 pr.	7 pr.	19–20 pr.	0 or 1 pr.	4–6 pr.[5]	1 pr.	5 pr.	6 pr.	7 pr.	7 pr.	29
	4 pr.	4 pr.	5 pr.	10–11 pr.	5–7 pr.	7–8 pr.		16–18 pr.	7–9 pr.	13 pr.	5 pr.	7 pr.	6 pr.	5 pr.	30
Sternum															
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	31
	6	8	6	5	5	4					4	3–4	3–5	3–4	32
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	33
											4 pr.				34
Pectoral Girdle															
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35
	*	*	*	*	*	*	*	*	*	*	*	*	*	*	36
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37
	*	*	0	0	0	0	0	0	0	0	1 pr.	1 pr.	1 pr.	1 pr.	38
	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	39
Upper Extremity															
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	40
	1	1	1	1	1	1	1	1 f. at 1 extr.	1	1	1	1	1	1	41
	1	1	1	*	1	1	1		1	1	1	1	1	1	42
										5					43
	1	1	1	1	1	1	1	1	1		1	1	1	1	44
				1	1	1	1	1	1		1				45
	1	1	1	1	1	1	1	1	1	Homol-	1	1	1	1	46
	1	1	1	1	1	1	1	0	0	ogies	1	1	1	1	47
	0	0	0	0	0	0	0	0	0	diffi-	0	0	0	1	48
	1	1	0 or 1	0	0	0	1	1	0	cult	1	1	1	1	49
	1	1	1		1	1	1	1	1		1	1	1	1	50
	1	1	1	1	1	1	1	1	0 or 1		1	1	1	1	51
	1	1	1	1	1	1	1	1	1		1	1	1	1	52
			5				5	5	5		5	5		5	53
	*	*		0	0	0				0			*		54
	1	1		*	1					1			1		55
	1	1		1	1	1				1			1		56
	1	1		*	1	1				1			1		57
	1	1		0	*	1				1			1		58
	2	2	2	0	0	0	2	2	*2	0	2	2	2	2	59
	3	3	3	0	0	3	3	3		3	3	3	3	3	60
	3	3	3	3	3	3	3			5	3	3	3	3	61
	3	3	3	3	3	3	3			5	3	3	3	3	62
	3	3	3	0	0	3	3	3		3	3	3	3	3	63

by union of basisphenoid, presphenoid, alisphenoids, orbitosphenoids, pterygoids, and possibly other skull bones. /3/ Name used in mammalian intermediate ribs are present at the ventral ends of each of the first 6 pairs of vertebral ribs.

Dist. = distally; extr. = extremities; f. = fused; innom. = innominate; pn. = prenasal;

	Bone	Monotremata		Marsupialia	Insectivora	Chiroptera	Primates					
		Platypus, duckbilled (Platypus ornithorhynchus)	Anteater, spiny (Tachyglossus spp)	Opossum, Virginia (Didelphis virginiana)	Shrew, common (Sorex personatus)	Bat, big brown (Eptesicus fuscus)	Lemur (Lemur macaco)	Monkey, New World (Ateles belzebuth)	Monkey, Old World (Cercopithecus spp)	Chimpanzee (Pan troglodytes)	Man (Homo sapiens)
	Pelvic Girdle										
64	Epipubic	1 pr.	1 pr.	1 pr.	0	0	0	0	0	0	0
65	Ilium	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.
66	Ischium										
67	Pubis										
	Lower Extremity										
68	Femur	1	1	1	1	1	1	1	1	1	1
69	Patella	1	1	0	1	1	1	1	1	1	1
70	Tibia	1	1	1	1	1	1	1	1	1	1
71	Fibula	1	1	1	1	1	1	1	1	1	1
	Tarsus										
72	Astragalus[3] (talus)	1	1	1	1	1	1	1	1	1	1
73	Calcaneus	1	1	1	1	1	1	1	1	1	1
74	Navicular	1	1	1	1	1	1	1	1	1	1
75	Cuneiform, medial	1	1	1	1	1	1	1	1	1	1
76	Cuneiform, intermediate	1	1	1	1	1	1	1	1	1	1
77	Cuneiform, lateral	1	1	1	1	1	1	1	1	1	1
78	Cuboid	1	1	1	1	1	1	1	1	1	1
79	Metatarsus	5	5	5	5	5	5	5	5	5	5
80	First										
81	Second										
82	Third										
83	Fourth										
84	Fifth										
	Phalanges										
85	First digit	2	2	2	2	2	2	2	2	2	2
86	Second digit	3	3	3	3	3	3	3	3	3	3
87	Third digit	3	3	3	3	3	3	3	3	3	3
88	Fourth digit	3	3	3	3	3	3	3	3	3	3
89	Fifth digit	3	3	3	3	3	3	3	3	3	3

/1/ The order Edentata is so diversified that all skeletal modifications cannot be included. /2/ P. phocaena has 5 digits: the first is rudimentary name, used in human anatomy(Nomina Anatomica, 1955), is in parentheses.

138. BONE: SOME

Values in parentheses are estimates "b" and "c" of the 95% range

Compressive Strength: a measure of the load or force per unit area required to crush a body. Tensile Strength: a measure of the load or force per on the immediately adjacent part. Torsion Strength: a measure of the load or force per unit area required to produce torsion or twisting of a body. This is also called Young's modulus. Specific Gravity: a ratio of the weight of a volume of material to the weight of the same volume of water.

Part I: MAN

	Specimen Type, Condition and Loading[1]	Value		Specimen Type, Condition and Loading[1]	Value
	Modulus of Elasticity	kg/sq mm (x 1000)		Tensile Strength	kg/sq mm
	Tension		18	Compact, fresh	9.97(5.74-11.00)[c]
1	Compact, fresh	2.31(1.82-2.71)[c]	19	Compact, dry	11.48(10.02-15.27)[c]
2	Compact, embalmed wet	1.60(0.79-2.15)[c]	20	Compact, embalmed wet	8.32(4.81-10.90)[c]
3	Compact, embalmed dry	1.88(1.20-2.58)[c]	21	Compact, embalmed dry	10.78(6.14-18.12)[c]
	Compression			Shearing Strength	
4	Compact, embalmed dry	1.94(1.42-2.27)[c]	22	Compact, fresh, parallel	5.03(4.25-6.50)[c]
	Bending		23	Compact, fresh, perpendicular	11.85(10.50-12.99)[c]
5	Compact, fresh	2.21(1.89-2.47)[c]	24	Compact, embalmed wet, perpendicular	6.89(4.23-10.76)[c]
6	Compact, dry	2.29(1.96-2.65)[c]	25	Compact, embalmed dry, perpendicular	5.62(2.52-8.87)[c]
	Compressive Strength	kg/sq mm	26	Spongy, fresh, parallel[2]	0.20(0.14-0.29)[c]
7	Compact, fresh, parallel	14.74(11.37-19.37)[c]	27	Spongy, fresh, perpendicular[2]	0.56(0.45-0.62)[c]
8	Compact, dry, parallel	17.37(11.25-23.19)[c]		Torsion Strength	
9	Compact, embalmed wet, parallel	13.36(9.00-17.72)[b]	28	Compact, fresh	7.9(7.097-9.31)[c]
10	Compact, embalmed wet, perpendicular	14.35(9.996-18.39)[c]	29	Compact, embalmed dry	7.47(5.87-9.27)[b]
11	Compact, embalmed wet, radially	11.94(5.48-19.40)[b]		Other Properties	
12	Compact, embalmed wet, tangentially	10.78(6.84-14.72)[b]	30	Density, compact, dry, g/cu mm	1.87(1.56-2.07)[c]
13	Compact, embalmed dry, parallel	20.52(16.90-24.14)[b]	31	Hardness[3], compact, wet	4.2(-59 to 21)[c]
14	Compact, embalmed dry, perpendicular	16.84(14.63-30.11)[b]	32	Hardness[3], compact, embalmed wet	16.3(-25 to 38)[c]
15	Compact, embalmed dry, radially	13.50(9.08-17.92)[b]	33	Hardness[3], compact, embalmed dry	25.2(0-24 to 47)[c]
16	Compact, embalmed dry, tangentially	13.1(8.81-17.41)[b]	34	Specific gravity, compact, fresh	1.93(1.80-1.997)[c]
17	Spongy, fresh parallel[2]	2.81(1.48-5.09)[c]			

/1/ Specimens loaded as indicated with long axis of bone or fiber. /2/ Specimens punched out from head and neck of femur. /3/ Rockwell factor, 1/8 inch steel ball penetrance, 45 kg load for 10 seconds.

Part II: OTHER ANIMALS

	Specimen Type, Condition and Loading[1]	Value		Specimen Type, Condition and Loading[1]	Value
	Modulus of Elasticity: Bending	kg/sq mm (x 1000)		Modulus of Elasticity: Bending (concluded)	kg/sq mm (x 1000)
1	Calf, compact, fresh	1.80(1.71-1.89)[c]	5	Swine, domestic, compact, fresh	2.09(1.76-2.41)[c]
2	Fox, compact, fresh	2.24(2.08-2.37)[c]	6	Wolf, compact, fresh	2.24(1.90-2.71)[c]
3	Ox, compact, fresh	2.44(2.13-2.47)[c]	7	Goose, domestic, compact, fresh	1.80(1.68-1.96)[c]
4	Pig, wild, compact, fresh	1.75(1.60-1.90)[c]			

/1/ Specimens loaded as indicated with long axis of bone or fiber.

MAMMALS (Concluded)

pr. = pair; prox. = proximally; sph. = sphenoid; var. = variable; * = rudimentary bone.

Carnivora			Ungulata				Pro-boscidea	Sirenia	Cetacea		Edentata[1]	Rodentia		Lago-morpha	
Cat, domestic (Felis domestica)	Dog (Canis familiaris)	Seal, harbor (Phoca vitulina)	Horse (Equus caballus)	Cattle, domestic (Bos taurus)	Swine (Sus scrofa)	Elephant, Asiatic (Elephas maximus)	Manatee (Trichechus spp)	Porpoise, harbor (Phocaena phocaena)	Whale, finback (Balaenoptera physalus)	Armadillo, nine-banded (Dasypus novemcinctus)	Guinea pig (Cavia lechudii pallidior)	Rat, Norway (Rattus norvegicus)	Hare, varying (Lepus americanus virginianus)		
Pelvic Girdle															
0	0	0	0	0	0	0	0	0	0	0	0	0	0		64
1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	*	0	0	Innom., f. with sacrum	1 pr., innom.	1 pr., innom.	1 pr., innom.		65
							0	*	*						66
							0	0	0						67
Lower Extremity															
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	68
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	69
1	1 may be f. dist.	1 f.	1	1	1	1	1	0	0	0	1	f. at	1	1	70
1	1 f. dist.	1 prox.	*	*	1	1	1	0	0	0	1	extr.	1	1	71
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	72
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	73
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	74
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	75
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	76
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1 or 0	77
1	1	1	1	1	1	1	1	0	0	0	1	1	1	1	78
		5				5	5	0	0	0	5	5	5		79
*	*		0	0	0									0	80
1	1		1	1	1									1	81
1	1		1	1	1									1	82
1	1		*	1	1									1	83
1	1		0	0	1									1	84
*	*	2	0	0	0	1	1	0	0	0	2	2	2	0	85
3	3	3	0	0	0	3	3	0	0	0	3	3	3	3	86
3	3	3	3	3	3	3	3	0	0	0	3	3	3	3	87
3	3	3	0	3	3	3	3	0	0	0	3	3	3	3	88
3	3	3	0	3	3	3	3	0	0	0	3	3	3	3	89

and cartilaginous, and in the remaining four, varying numbers of phalanges become ossified. /3/ Name used in mammalian anatomy; alternate

PHYSICAL CHARACTERISTICS

(cf Introduction). Data in Part III are presented for purposes of comparison.

unit area required to pull a body apart. Shearing Strength: a measure of the load or force per unit area required to cause one part of a body to slide
Modulus of Elasticity: a number representing the degree of stiffness of a material; obtained by dividing the unit stress by the unit deformation.
Density: the weight of a unit volume of material at a specific temperature.

Part II. OTHER ANIMALS (Concluded)

	Specimen Type, Condition and Loading[1]	Value		Specimen Type, Condition and Loading[1]	Value
	Compressive Strength	kg/sq mm		Specific Gravity	
8	Calf, compact, fresh, parallel	12.31(10.92-13.44)[c]	22	Calf, compact, fresh	2.101
9	Ox, compact, fresh, parallel	17.19(12.73-23.42)[c]	23	Cow, compact, fresh	1.980
10	Ox, compact, dry, parallel	15.46(12.87-17.74)[c]	24	Fox, compact, fresh	1.995(1.985-2.006)[c]
11	Ox, compact, fresh, perpendicular	19.81(14.53-23.50)[c]	25	Horse, compact, fresh	1.961(1.924-1.998)[c]
12	Pig, wild, compact, fresh, parallel	13.78(12.30-14.17)[c]	26	Ox, compact, fresh	2.024(1.953-2.024)[c]
13	Swine, domestic, compact, fresh, parallel	13.95(9.996-14.79)[c]	27	Pig, wild, compact, fresh	2.060
14	Wolf, compact, fresh, parallel	19.96(18.69-20.81)[c]	28	Swine, domestic, compact, fresh	1.883(1.802-1.965)[c]
	Tensile Strength		29	Swine, suckling, compact, fresh	1.707
15	Calf, compact, fresh, parallel	8.61(5.996-13.32)[c]	30	Wolf, compact, fresh	1.970(1.951-1.984)[c]
16	Ox, compact, fresh, parallel	10.998(9.996-14.99)[c]	31	Chicken, compact, fresh	1.786
17	Ox, compact, dry, parallel	12.43(6.38-16.87)[c]	32	Duck, domestic, compact, fresh	1.840
18	Ox, compact, fresh, perpendicular	9.12(7.77-10.65)[c]	33	Frog, compact, fresh	1.507
19	Pig, wild, compact, fresh, parallel	10.29		Density	g/cu cm
20	Swine, domestic, compact, fresh, parallel	10.80	34	Dog, compact, embalmed dry	1.85(1.59-2.04)[c]
21	Wolf, compact, fresh, parallel	10.77(9.16-12.35)[c]			

/1/ Specimens loaded as indicated with long axis of bone or fiber.

Part III: WOOD AND STEEL

	Specimen Type and Loading[1]	Value		Specimen Type and Loading[1]	Value		Specimen Type and Loading[1]	Value
	Tensile Strength[2]	kg/sq mm		Compressive Strength[3](concluded)	kg/sq mm		Shearing Strength[3](concluded)	kg/sq mm
1	Conifers, perpendicular	0.2	10	Pine, shortleaf,		17	Pine, shortleaf	0.8
2	Elm, parallel	20.4		parallel	4.5	18	Redwood	0.5
3	Fir, Douglas, parallel	8.2	11	Pine, shortleaf,			Tensile Strength	
4	Hardwood, perpendicular	0.6		perpendicular	0.6	19	Cast iron, gray iron	10.5-12.7
5	Hickory, parallel	22.5	12	Redwood, parallel	3.6	20	Steel, extra soft	31.6-38.7
6	Pine, longleaf, parallel	12.2	13	Redwood, perpendicular	0.4	21	Wrought iron	29.5-36.6
	Compressive Strength[3]			Shearing Strength[3]			Modulus of Elasticity	kg/sq mm (x 1000)
7	Fir, Douglas, parallel	3.5	14	Fir, Douglas	0.6	22	Cast iron, gray iron	8.4-9.8
8	Pine, Norway, parallel	5.3	15	Pine, longleaf	0.7	23	Steel, extra soft	21.1
9	Pine, Norway, perpendicular	0.6	16	Pine, Norway	0.8	24	Wrought iron	18.3-20.4

/1/ Wood specimens loaded as indicated with fibers. /2/ 15% moisture content. /3/ Small size, air-seasoned.

139. BONE MARROW DIFFERENTIAL CELL COUNT: MAN AND DOG

Values for man based on sternal aspirations, 750 adults, male and female. Values for dog based on rib extruations, 187 adult dogs. All values are percents and are the grand mean of results of several laboratories using different techniques. Ranges of investigators' means are in parentheses.

	Cell Type	Man	Dog
1	Red	19.1	43.6
2	Early forms	2. 9	5. 4
3	Proerythroblasts	0. 5(0. 2-4. 0)	0. 5(0. 3-0. 6)
4	Early normoblasts	2. 4(1. 5-5. 8)	4. 9(1. 5-7. 8)
5	Late forms	16. 2	38. 2
6	Intermediate normoblasts	11. 7(5. 0-26. 4)	22. 3(11. 0-26. 0)
7	Late normoblasts	4. 5(1. 6-21. 5)	15. 9(4. 6-17. 4)
8	White	70. 0	54. 9
9	Granulocytic	57. 4	52. 2
10	Myelobiasts	1. 2(0. 3-3. 1)	1. 2(0. 6-2. 4)
11	Progranulocytes	3. 0(0. 5-4. 5)	1. 4(0. 7-2. 8)
12	Myelocytes	8. 7(0. 9-20. 3)	4. 8(2. 7-8. 9)
13	Metamyelocytes	11. 0(5. 6-22. 0)	7. 4(3. 4-15. 3)
14	Band cells	17. 9(6. 1-36. 0)	24. 6(11. 7-42. 0)
15	Segmented cells	15. 6(8. 7-27. 0)	9. 6(3. 9-30. 0)[1]
16	Eosinophils		3. 1(2. 0-4. 7)
17	Other	12. 6	2. 7
18	Lymphocytes	9. 8(2. 7-24. 0)	0. 9(0. 7-1. 9)
19	Monocytes	1. 4(0. 7-2. 8)	0. 2(0. 0-0. 2)
20	Megakaryocytes	0. 2(0. 03-0. 4)	0. 4(0. 1-0. 6)
21	Plasmacytes	0. 6(0. 1-1. 5)	0. 3(0. 0-0. 4)
22	Reticulum cells	0. 6(0. 03-1. 6)	0. 9(0. 0-1. 0)
23	Non-identifiable	10. 9	1. 5
24	Unclassified cells	1. 7(0. 02-3. 3)	1. 5(0. 0-3. 0)
25	Disintegrated cells	9. 2(1. 1-20. 8)	

[1] Includes basophils (0. 05-0. 2).

140. BONE MARROW DIFFERENTIAL CELL COUNT, PREGNANCY: MAN

Values based on 10 ml sternal marrow aspirated from each of 40 pregnant and 28 non-pregnant females. Values and ranges are numbers of cells per cu mm. Because of extreme variability in the "normal" range, averages should be considered with caution. Data adapted from Pitts, H. H., and Packham, E. A., Arch. Int. Med., 64:471-482, 1939.

	Cell Type[1]	1st Trimester	2nd Trimester	3rd Trimester	Non-pregnant
		cells/cu mm			
1	Proerythroblasts	56(0-136)	73(0. 203)	61(0-210)	28(0-122)
2	Early normoblasts	749(86-1314)	797(251-1875)	1050(51-3937)	616(62-1396)
3	Intermediate normoblasts	1139(259-2628)	1803(314-7000)	1865(51-8636)	1199(134-2904)
4	Late normoblasts	944(28-2700)	839(250-2000)	836(119-2730)	453(43-1089)
5	Myeloblasts	63(0-328)	173(0-1250)	96(0-635)	89(0-279)
6	Progranulocytes	378(36-900)	462(69-2500)	341(0-1460)	251(11-736)
7	Early neutrophilic myelocytes	262(0-675)	646(0-3500)	362(51-1050)	147(0-630)
8	Myelocytes, eosinophilic[2]	218(28-494)	251(0-1400)	167(0-700)	147(0-544)
9	Myelocytes, neutrophilic	2267(172-4336)	3229(659-13, 125)	2138(391-7937)	1568(168-4140)
10	Metamyelocytes, neutrophilic	2165(259-5913)	2623(230-10, 250)	1879(340-4900)	1437(168-4324)
11	Band neutrophils	11, 659(2, 189-28, 251)	15, 415(3, 077-46, 250)	11, 819(4, 901-29, 400)	6, 048(1, 091-14, 490)
12	Segmented neutrophils	5445(4050-8835)	5, 441(1, 575-11, 750)	4613(394-8680)	3565(1132-7084)
13	Segmented eosinophils[3]	371(48-1140)	299(18-990)	228(0-700)	246(60-642)
14	Segmented basophils	78(0-197)	47(0-125)	49(0-191)	53(0-184)
15	Lymphocytes	3975(2894-6300)	4, 467(1, 686-10, 000)	3719(1318-5400)	3428(1721-6520)
16	Monocytes	333(40-965)	245(0-642)	194(0-732)	312(32-717)
17	Disintegrated cells	4684(1382-8100)	4, 675(1, 037-11, 500)	4, 480(1, 329-11, 900)	3578(1081-6534)
18	Total nucleated cells	34, 580(14, 400-65, 700)	41, 510(15, 700-125, 000)	33, 930(16, 900-70, 000)	23, 100(7, 500-46, 000)

[1] Proplasmacytes, plasmacytes, basophilic myelocytes, early myelocytes (eosinophilic and basophilic) not tabulated but present in less than 0. 1 per cent. [2] Includes eosinophilic metamyelocytes. [3] Includes band eosinophils.

141. HISTOCHEMICAL PROPERTIES, BLOOD AND BONE MARROW CELLS: MAN

C = cytoplasm proper; G = specific granules; J = juxtanuclear bodies; M = mitochondria; N = nucleoli.

	Cell Type	Lipid[1]	Phospho-lipid[2]	Acid Phosphatase[3]	Alkaline Phosphatase[3]	Ribonucleo-protein[4]	Carbohydrate[5]	Peroxidase[6]
1	Nuclei	Neg	Neg	Pos	Pos[7]	Pos N	Neg	
	All types							
	Cytoplasm							
2	Myeloblasts	Pos M	Pos M	Neg		Pos C[8]	Neg	Neg
3	Progranulocytes	Pos GM	Pos G?M	Pos G	Neg	Pos C[8]	Neg	Neg
4	Myelocytes	Pos GM	Pos G?M	Pos CG	Neg[9]	Neg	Pos?, 10	Pos G
5	Metamyelocytes	Pos G[11]	Pos G?	Pos G	Pos C[8, 10]	Neg	Pos?, 10	Pos
6	Segmented neutrophils	Pos G[11]	Pos G?	Pos G	Pos C[8, 10]	Neg	Pos?, 10	Pos
7	Segmented eosinophils	Pos G	Pos G	Pos G	Neg	Neg	Pos G	Pos
8	Segmented basophils	Pos G	Pos G?			Neg	Pos	Pos
9	Tissue eosinophils	Pos G	Pos GM	Neg	Neg	Neg	Pos G[10]	Neg
10	Lymphoblasts	Pos M	Pos M			Pos C[8]	Pos?	Pos
11	Lymphocytes	Neg	Neg	Pos JG	Neg[12]	Pos C[8]	Neg[13]	Neg
12	Monocytes	Pos GM	Pos G				Pos C	Neg
13	Megakaryocytes	Pos GM	Pos G?M	Pos[8]	Pos C[8]	Pos C[8, 9]	Pos[10]	Pos[14]
14	Thrombocytes	Neg	Pos C[8]G			Neg	Pos[10]	
15	Proerythroblasts ("rubriblasts")	Pos M	Pos M	Pos J	Neg	Pos C[8]	Neg	Neg
16	Early normoblasts ("prorubricytes")	Pos M	Pos M	Pos J	Neg	Pos C[8]	Neg	Neg
17	Intermediate normoblasts ("rubricytes")	Pos M	Pos M		Neg	Pos C[8]	Neg	Neg
18	Late normoblasts ("metarubricytes")	Neg	Neg		Neg	Pos C[8]	Neg	Neg
19	Erythrocytes	Neg	Neg[8]	Neg[15]	Neg	Neg	Neg	Pos
20	Plasmacytes			Pos JG	Pos C[8]	Pos C	Pos?	Neg
21	Reticulum cells	Pos G	Pos G[6]	Pos G		Pos CG	Pos G[16]	Neg
22	Mast cells	Pos G[17]	Pos G	Pos G	Pos G	Pos CG	Pos CG[17]	Pos

[1] Stained with Sudan black B unless otherwise specified. [2] Detected by acid-hematein method; negatively evaluated by pyridine extraction method. [3] Detected by modified Gomori method using glycerophosphate substrate. [4] Detected by Feulgen reaction; negatively evaluated by digestion with ribonuclease. [5] Detected by either periodic acid-Schiff, or by Gomori silver-methenamine methods. [6] Detected by benzidine-peroxide. [7] Controversial. [8] Diffuse staining. [9] May be positive (Nabinovitch and Andreucci). [10] As glycogen. [11] Stable sudanophilia. [12] May be positive. [13] Positive according to Stowell; Wachstein. [14] Trace. [15] Positive when substrate is ATP. [16] Probably is phagocytosed material (Lillie). [17] Granules positive in many cells, negative in others.

142. COMPARATIVE ANATOMY OF THE HEART: CHORDATES

	Chordate	Location in Body	Chambers Forming Heart	Atrioventricular Valves	Semilunar Valves	Septum Atriorum	Septum Ventriculorum
1	Amphioxus	Heart lacking; aortic arches are contractile.					
	Fishes	Cervical.	One atrium, one ventricle.	Present, two or more cusps.	Numerous, in series, in conus arteriosus.	None.	None.
2	Cyclostomes						
3	Selachii						
4	Ganoidii						
5	Teleostei[1]				One set (not in series) in conus arteriosus.		
6	Dipnoi		Two atria, one ventricle.	Lacking but function performed by a fibrocartilaginous swelling.	Numerous in conus; now beginning to divide.	Present.	Incomplete.
	Amphibia	High in thorax.	Two atria, one ventricle.		Present in bulbis cordis.	Perforated.	
7	Urodela, with lungs						
8	Urodela, lungless		One atrium, one ventricle.	Present, right and left cusps.			
9	Anura		Two atria, one ventricle.	Present, dorsal and ventral cusps.		Solid.	
10	Reptilia	High or low in thorax[2].	Two atria, two ventricles.	Two atrioventricular valves.	Present in pulmonary and aortic trunks.		Incomplete or complete[3].
11	Aves	Low in thorax.					Complete.
12	Mammalia[4]						

	Chordate	Wall Structure of Chambers	Conus and Truncus Arteriosus	Sinus Venosus Size and Valves	Chambers Containing: Arterial Blood	Mixed Blood	Venous Blood
1	Amphioxus	Heart lacking; aortic arches are contractile.					
	Fishes	Atrium generally smooth; ventricles with inner surface netlike or with larger trabeculae.	Conus long and well-developed; truncus represented by ventral aorta.	Sinus venosus large; sinoatrial valve generally well-developed.	None in heart.		Atria and ventricle.
2	Cyclostomes						
3	Selachii		Conus long and well-developed; truncus short and little developed.				
4	Ganoidii		Conus moderately long; truncus long, thin-walled.				
5	Teleostei[1]		Conus very much reduced; truncus thick-walled and well-developed.				
6	Dipnoi		Conus and truncus shortened; bent somewhat spirally; partly or completely separated into two halves.	Opens into right atrium.	Left atrium.	Ventricle.	Right atrium.
	Amphibia	Atria smooth; ventricle with many muscle bands transversing cavity, giving it a spongy structure.	Conus incorporating into wall of heart; truncus divided into pulmonary and aortic portions.	Reduced in size by partial incorporation in right atrial wall; valve persists.	Left atrium.	Ventricle.	Right atrium.
7	Urodela, with lungs						
8	Urodela, lungless		Truncus lacks septum.		None	None	Atrium, ventricle
9	Anura		Conus incorporating into wall of heart; truncus divided into pulmonary and aortic portions.	Sinus generally not recognizable as such on external aspect of heart; valve persists.	Left atrium.	Ventricle.	Right atrium.
10	Reptilia	Atria generally smooth; ventricles with trabeculae cordis but ventricular cavities not divided by muscle bands.	Conus entirely incorporated in ventricular mass; truncus directly from ventricles; truncus divided.	Sinus further reduced and valve vestigial.	Left atrium.	Ventricle.	Right atrium.
11	Aves[5]						
12	Mammalia[6]	Atria with moderate ridging (musculi pectinati); ventricles with trabeculae.	No conus; truncus completely divided.	Sinus lacking; vestiges of valve are "valvae of the inferior vena cava," "valve of the coronary sinus."	Left atrium and left ventricle.	None.	Right atrium and right ventricle.

/1/ Teleostei in general. /2/ High in lizards and turtles; low in snakes and crocodiles. /3/ Incomplete in some lizards and snakes; complete in others, e.g., crocodiles. /4/ Mammals in general, including man. /5/ Includes also crocodiles.

143. MALE GENITALIA, DIMENSIONS AND WEIGHT: MAMMALS

Values in parentheses are averages of ranges reported in the literature. L = Length; T = Thickness; W = Width; Wt = Weight.

	Species	Testes				Epididymis	Ductus Deferens	Seminal Vesicles		Prostate Gland			Bulbourethral Gland		Penis[1]
		L_0, cm	W_0, cm	T_0, cm	Wt_0, g	L_1, m	L_1, cm	L_0, cm	W_0, cm	L_0, cm	W_0, cm	T_0, cm	L_0, cm	W_0, cm	L_0, cm
1	Man (Homo sapiens)	4.2[2]	3.8[2]	2.5[2]	(20-35)	8[3]	(38-61)	4.3	1.7[4]	4.0	2.8	1.9	Size of pea		13[5]
2	Cat (Felis catus)	1.5	1		2.016						1		Small[5]		
3	Cattle (Bos taurus)	11.5	7	6-7	300(284-340)		(25-38)	11.5	5	3.8	1.3	1.3	Very small		91
4	Dog (Canis familiaris)	Relatively small						Absent		Large (variable)			Absent		10
5	Goat (Capra hircus)	10			(255-284)	(40-60)				Disseminate					40
6	Guinea pig (Cavia porcellus)				2.8										
7	Horse (Equus caballus)	11	5	7	(225-300)	(72-86)	(15-20)	17.5	5		2[7]		5	2.5	51
8	Mouse (Mus musculus)							Long, narrow			3 pairs				
9	Rabbit (Oryctolagus cuniculus)	Ellipsoidal			2.6			Single, unpaired		2-lobed with isthmus			Paired, small		4
10	Rat (Rattus rattus)							Long, narrow			2 pairs				
11	Sheep (Ovis aries)	10			(255-284)	(40-60)		5.7	2.5	Disseminate			Relatively large		40
12	Swine (Sus scrofa)				(151-871)	(62-64)[3]	(25-30)	14	4.4		2.5[8]		12	3[9]	(46-51)

/1/ Non-erect. /2/ Age, 20-60 yr. /3/ Extended. /4/ T = 0.9 cm. /5/ Age, 20-25 yr. /6/ Wt = 0.4-0.5 g. /7/ Diameter at isthmus. /8/ Wt = 15-26 g. /9/ Wt = 146-209 g.

144. FEMALE GENITALIA, DIMENSIONS AND WEIGHT: MAMMALS

The size and weight of the ovaries depend on the stage of the ovarian cycle and the number and size of corpora lutea and follicles. Uterine weight is also dependent on the stage of the ovarian cycle as well as age of the animal, size of breed, and virgin or parous condition of the uterus. Values in parentheses are averages of ranges reported in the literature. L = Length; T = Thickness; W = Width; Wt = Weight.

	Species	Ovaries				Uterine Tubes	Uterus					Vagina	Vulva
							Total Organ	Horns	Body	Cervix			
		L_0, cm	W_0, cm	T_0, cm	Wt_0, g	L_1, cm	Wt_0, g	L_1, cm	L_0, cm	L_0, cm	W_0, cm	L_1, cm	L_0, cm
1	Man (Homo sapiens)	3.5	1.8	1.2	7[1]	(7-14)	(33-41)[2, 3]		8	(2.5-3.5)[2]		9[1]	
2	Cat (Felis catus)	1				5		10	2			2	2
3	Cattle (Bos taurus)	3.8	2.5		19	(20-23)	700	38	3.8	10	2.5	(25-30)	10
4	Dog (Canis familiaris)		2			(5-7.6)		(11-15)	(2-3)	1		(7.5-15)	
5	Ferret (Mustela putorius)						0.4[5]						
6	Goat (Capra hircus)		1.5			(10-15)		(10-12)	2	4		(10-12)	(2.5-3)
7	Guinea pig (Cavia porcellus)					0.3		(5-6)				(2.5-4)	
8	Horse (Equus caballus)	7.5		3.5	(70-80)	(20-30)		25	(18-20)(L);10(W)	(5-8)	3.8	(15-20)	(10-13)
9	Rabbit (Oryctolagus cuniculus)	1.5	0.7	0.6	0.55	10	8	(10-12)[6]		0.7[6]		(3.5-6)	4[7]
10	Sheep (Ovis aries)	1.5		1	(4-8)[8]	(10-15)		(10-12)	2.5	3.8		(7.5-10)	(2.5-3)
11	Swine (Sus scrofa)				(3.5-10)	(15-30)		(120-150)	5	10		(10-13)	7.5

/1/ After pregnancy. /2/ Virgin uterus. /3/ Parous uterus approximately 35 g heavier. /4/ For posterior wall; anterior wall 7 cm. /5/ Anestrus; estrus, 1 g; pseudopregnant, 5 g. /6/ Duplex uterus with two cervices opening into vagina. /7/ At vestibule. /8/ In breeding season, depending on number of ovulations; otherwise smaller.

145. KIDNEY MEASUREMENTS: VERTEBRATES

	Species	Body Weight	Kidney		Glomerulus					Species	Body Weight	Kidney		Glomerulus			
			Weight of One Kidney		Radius	Thousands per Kidney[1]	Vol/Kidney cu mm	Vol/g Kidney cu mm				Weight of One Kidney		Radius	Thousands per Kidney[1]	Vol/Kidney cu mm	Vol/g Kidney cu mm
		kg	g	% body wt	μ						kg	g	% body wt	μ			
1	Man	70	156	0.22	100	1095	4599	29	10	Ox	410	640	0.16	122	3982	29,860	47
2	Cat	2.8	8	0.29	66	184	227	28	11	Rabbit	1.9	6.5	0.34	71	199	300	46
3	Dog	9.1	31	0.34	90	408	1247	40	12	Rat, albino	0.24	0.75	0.31	61	31	30	40
4	Elephant	4545	3650	0.08	169	7510	151, 900	42	13	Rat, kangaroo	0.07	0.30	0.43	48	18.8	8.9	30
5	Ground hog	1.2	1.8	0.15	70	96	135	75	14	Swine	47	77	0.16	83	1193	2859	37
6	Guinea pig	0.56	1.9	0.34	63	76	79	42	15	Chicken	2.5				429		
7	Monkey	3.9	9	0.23	83	187	447	50	16	Duck	3.67				994.5		
8	Mouse	0.02	0.12	0.61	37	12.4	2.6	21	17	Goose	5.4				829.5		
9	Opossum	2	5.2	0.26	88	91	256	49	18	Pigeon	0.232-0.420				137-176.5		

/1/ The number of glomeruli per kidney undergoes slow decrease after maturity and as the animal approaches senility.

146. SURFACE AREA RELATIONSHIPS: MAMMALS
Part I: SURFACE AREA FOR KNOWN HEIGHT AND WEIGHT: MAN

	Body Weight	Height cm																														
	kg	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260
1	5	.18	.20	.23	.26	.29	.33	.37	.42	.48	.55	.62														
2	10		.35	.36	.38	.41	.44	.48	.52	.57	.64	.69	.76													
3	15					.54	.57	.60	.63	.67	.72	.77	.83	.89												
4	20						.68	.72	.76	.80	.85	.91	.97	1.03												
5	25							.80	.84	.88	.93	.98	1.03	1.09	1.15											
6	30								.92	.96	1.01	1.05	1.10	1.16	1.22	1.28										
7	35									1.04	1.08	1.12	1.17	1.23	1.29	1.35	1.42									
8	40									1.11	1.15	1.20	1.25	1.30	1.36	1.42	1.48	1.55								
9	45										1.23	1.27	1.32	1.37	1.43	1.48	1.54	1.61								
10	50										1.30	1.34	1.39	1.44	1.49	1.54	1.60	1.67	1.74							
11	55										1.37	1.40	1.46	1.50	1.55	1.61	1.67	1.73	1.80							
12	60										1.44	1.48	1.52	1.57	1.62	1.67	1.73	1.79	1.85	1.92						
13	65											1.54	1.58	1.63	1.68	1.73	1.79	1.85	1.91	1.97						
14	70											1.61	1.65	1.70	1.75	1.80	1.85	1.91	1.96	2.02	2.08					
15	75											1.68	1.72	1.76	1.81	1.86	1.91	1.96	2.02	2.07	2.13					
16	80	All values are square meters of body surface area derived according to the method of Sendroy and Cecchini, 1954, (Sendroy, J., Jr., and Cecchini, L. P., 1954, J. Applied Physiology 7:1-12)										1.74	1.78	1.82	1.86	1.91	1.96	2.02	2.07	2.13	2.18	2.25				
17	85											1.81	1.84	1.88	1.92	1.97	2.02	2.07	2.13	2.18	2.24	2.31				
18	90											1.87	1.90	1.94	1.98	2.03	2.08	2.13	2.18	2.24	2.30	2.36				
19	95												1.97	2.01	2.05	2.09	2.14	2.18	2.24	2.30	2.36	2.42	2.48			
20	100												2.03	2.07	2.12	2.16	2.20	2.24	2.30	2.35	2.41	2.47	2.54			
21	105												2.10	2.14	2.18	2.22	2.26	2.31	2.35	2.41	2.47	2.53	2.60			
22	110												2.17	2.21	2.24	2.28	2.32	2.36	2.41	2.47	2.53	2.58	2.65	2.73		
23	115												2.23	2.27	2.30	2.33	2.38	2.42	2.47	2.53	2.58	2.64	2.71	2.78		
24	120													2.33	2.36	2.39	2.43	2.48	2.53	2.58	2.63	2.70	2.77	2.84	2.93	
25	125													2.39	2.42	2.45	2.49	2.53	2.58	2.63	2.69	2.76	2.83	2.90	2.97	
26	130													2.44	2.47	2.51	2.54	2.59	2.63	2.68	2.75	2.82	2.88	2.95	3.02	
27	135													2.50	2.53	2.56	2.60	2.64	2.69	2.74	2.81	2.87	2.93	3.00	3.08	
28	140													2.55	2.58	2.62	2.66	2.70	2.74	2.80	2.87	2.93	2.98	3.06		
29	145													2.61	2.63	2.67	2.71	2.75	2.80	2.86	2.92	2.98	3.04			
30	150													2.66	2.69	2.73	2.77	2.81	2.86	2.92	2.97	3.03	3.09			
31	155													2.72	2.74	2.78	2.83	2.87	2.92	2.97	3.03	3.08				
32	160													2.77	2.80	2.83	2.88	2.92	2.97	3.02	3.08					
33	165														2.86	2.89	2.93	2.97	3.02	3.07						
34	170														2.91	2.94	2.98	3.03	3.07							
35	175														2.96	2.99	3.03	3.08								
36	180														3.01	3.04	3.08									
37	185														3.06	3.09										

Part II: CONSTANTS FOR ESTIMATING SURFACE AREA: MAMMALS

Ranges in parentheses are estimates "c" and "d" of the 95% range (cf Introduction) for body weight and K-values, respectively. K-values are derived from surface area values taken from extensive literature sources, using the formula $K = A(\text{sq cm})/W^{2/3}(\text{g})$.

	Animal	Method[1]	Body Weight g.	K-value (Constant)		Animal	Method[1]	Body Weight g	K-value (Constant)
1	Antelope	T	8300	14.1	37	Mouse	S	16.4(10.4-22.0)	11.4(9.7-13.3)
2	Bat	S	64.6(12.7-36.4)	57.5(54.0-59.8)	38	Mouse	S	20.2	6.3
3	Bat	S	8(5-116)	44.5(44.0-45.0)	39	Mouse	M	(16.0-24.8)	9.0(8.4-9.4)
4	Cat	T	1550(1500-1600)	8.7(6.6-8.9)	40	Mouse, deer	S	22.0	8.5
5	Cat[2]	S	100(84-116)	10.0(9.9-10.0)	41	Mouse, field	S	29.0(26.0-31.0)	6.9(6.5-7.2)
6	Cat[2]	S	708(219-1389)	10.7(9.5-11.9)	42	Mouse, red back	S	22.0	7.1
7	Cattle[2]	S	375,000(163,000-641,000)	11.0(9.0-13.8)	43	Opossum	S	1200(1000-1300)	11.3(10.5-11.8)
8	Cattle	S	476,000(208,000-762,000)	9.3(8.1-10.8)	44	Rabbit[4]	S	32(26-40)	8.5
9	Hereford, thin[2]	S	241,000(89,000-407,000)	9.9(9.3-10.5)	45	Rabbit[4]	S	560(70-925)	9.7
10	Hereford, med[2]	S	315,000(78,000-493,000)	9.4(8.4-10.0)	46	Rabbit	T	1130(1120-1140)	10.0(9.0-11.0)
11	Hereford, fat[2]	S	314,000(171,000-549,000)	8.6(8.3-9.0)	47	Rabbit	T	2600	5.7
12	Cattle[2]	S	695,000(476,000-815,000)	7.6(7.3-7.9)	48	Rat, white	S	25(23-28)	9.5(9.4-9.6)
13	Dog	S	1070(130-3650)	10.1(9.3-11.0)	49	Rat	S	42(35-53)	10.5(10.1-10.8)
14	Dog	S	1080	11.0	50	Rat	S	80(50-129)	9.9(9.6-10.4)
15	Dog	T	9,500(8,900-10,100)	9.9(9.85-9.9)	51	Rat[3]	M	95(22-164)	7.6(7.3-8.8)
16	Dog	S & P	12,700(3,200-29,800)	11.6(10.2-12.5)	52	Rat	M	125(24-366)	7.5(6.6-8.3)
17	Dog	M	14,310(3,390-32,640)	11.2(10.3-12.1)	53	Rat	S	133(70-310)	11.6(10.9-12.1)
18	Dog	C	27,000	12.3	54	Rat	S	137(47-295)	9.0
19	Fox	T	6200(6100-6300)	13.0(12.9-13.2)	55	Rat	T	170(164-177)	7.15
20	Goat	T	15,100	10.5	56	Rat	S	176(25-461)	11.4(9.6-13.0)
21	Guinea pig	S	357(123-191)	10.4(10.1-10.8)	57	Rat	M	(19-418)	9.0
22	Guinea pig	S	206(123-269)	9.5(8.4-10.8)	58	Rat	S	(65-335)	10.5
23	Guinea pig	S	256(235-269)	8.6(8.4-8.9)	59	Sheep	T	17,680	11.0
24	Guinea pig[3]	S	323(160-810)	8.9(7.9-9.6)	60	Sheep	S	(21,800-29,100)	10.7
25	Guinea pig	S	373(148-650)	9.6(9.0-9.9)	61	Sheep	I	(2,200-68,000)	8.3
26	Guinea pig	T	400(380-420)	7.1	62	Sheep	S	(23,600-37,700)	8.5
27	Hedgehog	S	200	7.5	63	Sheep	S	(3,780-50,400)	9.1
28	Horse	C		9.0	64	Shrew, long-tailed	S	3.5	8.0
29	Horse	S	(407,000-555,000)	10.5	65	Shrew, short-tailed	S	20	7.0
30	Horse	I	(170,000-750,000)	(8.2-10.3)	66	Swine	S		8.8
31	Lion	T	64,200	12.3	67	Swine	T	40,110	15.3
32	Marten, pine	T	1400	8.8	68	Swine	I	(25,000-330,000)	9.0
33	Monkey	M	2670(800-6600)	11.8(10.8-13.2)	69	Swine	S	48,300(1,100-123,000)	9.9(8.6-12.4)
34	Mouse[3]	S	12.9	6.9	70	Whale, fin	P	160,000(115,000-220,000)	8.3(7.5-8.9)
35	Mouse	S	14.7(6.0-26.5)	7.9	71	Whale	P	43,000,000	11.1
36	Mouse	S	15.9(10.7-19.7)	10.5(10.4-10.5)	72	Woodchuck	M	1236	9.3

[1] Method of determining surface area. C = paper cover; I = surface integrator; M = mold method; P = perimeter method; S = skinning; T = triangulation. [2] "Empty" weight. [3] Starved animals. [4] With surface area of one side of ear only.

147. STATURE, WEIGHT, AND SURFACE AREA: MAN, VARIOUS NATIONALITIES AND TYPES

Values in parentheses are ranges and conform with the "b" estimate of the 95% range (cf Introduction).

	Race or Nationality		Stature		Weight		Surface Area			Race or Nationality		Stature		Weight		Surface Area	
			cm	in	kg	lb	sq m^2					cm	in	kg	lb	sq m^2	
1	Aeta, Pygmoids (Bataan)	♂	148(138-158)	58(54-62)	42(31-53)	91(69-114)	1.29(1.11-1.47)	17		Chinese (Canton)	♀	148(138-158)	58(54-62)	54(37-71)	119(82-156)	1.43(1.19-1.67)	
2	Aeta, Pygmoids (Bataan)	♀	138(131-145)	54(51-57)	37(29-44)	80(65-96)	1.17(1.05-1.29)	18		English, students (Oxford)	♂	178(166-190)	70(65-75)	69(55-83)	151(120-182)	1.82(1.60-2.04)	
3	Aeta, Pygmoids (Zambales)	♂	148(139-157)	58(55-62)	40(32-49)	89(70-108)	1.28(1.14-1.42)	19		English, convicts	♂	167(153-181)	66(60-71)	65(50-80)	143(110-177)	1.70(1.45-1.95)	
4	Aeta, Pygmoids (Zambales)	♀	138(129-148)	54(51-58)	34(26-42)	75(57-92)	1.14(0.98-1.30)	20		French, workers	♂	169(157-181)	66(62-71)	67(51-83)	147(112-182)	1.73(1.51-1.95)	
5	African, Gobauoin (Somaliland)	♂	168(154-183)	66(61-72)	58(44-71)	127(96-157)	1.63(1.39-1.87)	21		French, workers	♀	159(150-168)	62(59-66)	56(42-70)	123(92-155)	1.54(1.34-1.74)	
6	African, Gobauoin (Somaliland)	♀	157(148-166)	62(58-65)	50(42-67)	111(114-148)	1.57(1.41-1.73)	22		Indochinese (Cambodja)	♀	149(140-159)	59(55-62)	53(37-68)	116(82-150)	1.44(1.20-1.68)	
7	Kung, Bushmen (Kalahari)	♂	157(143-170)	62(56-67)	40(31-50)	89(68-110)	1.33(1.13-1.53)	23		Indochinese (Hué)	♀	146(136-156)	57(53-61)	43(31-54)	94(69-119)	1.28(1.10-1.46)	
8	Morocco, natives	♂	169(158-182)	66(62-72)	64(50-78)	140(111-170)	1.71(1.47-1.95)	24		Indochinese (Tonkin)	♀	160(150-170)	63(59-67)	57(49-65)	126(108-144)	1.55(1.35-1.75)	
9	Negroes (West Africa)	♂	167(149-186)	66(58-73)	57(42-72)	125(93-158)	1.61(1.34-1.88)	25		Irish (North)	♂	172(160-184)	68(63-72)	68(51-84)	149(112-186)	1.77(1.53-2.01)	
10	Tunisia, natives	♂	173(163-183)	68(64-72)	62(53-71)	137(117-156)	1.70(1.56-1.84)	26		Italians	♂	168(155-181)	66(61-71)	63(44-82)	138(97-180)	1.81(1.50-2.12)	
11	Albanians (South Italy)	♂	164(153-175)	64(60-69)	61(49-73)	135(108-160)	1.64(1.40-1.88)	27		Italians	♀	156(143-170)	61(56-67)	52(34-70)	114(75-154)	1.64(1.31-1.97)	
12	Americans, white	♂	177(164-191)	70(64-75)	70(55-86)	156(121-190)	1.85(1.61-2.09)	28		Japanese	♂	159(149-170)	63(59-67)	53(38-68)	116(83-150)	1.55(1.31-1.79)	
13	Americans, white	♀	163(153-173)	64(60-68)	56(40-72)	123(88-158)	1.61(1.34-1.88)	29		Otomi (Mexican Indian)	♂	158(148-167)	62(58-66)	53(43-64)	117(94-141)	1.52(1.36-1.70)	
14	Andamanese (Indian Ocean)	♂	148(135-161)	58(53-63)	45(36-54)	98(79-118)	1.35(1.17-1.53)	30		Semang (Malaya)	♂	154(141-167)	60(55-66)	41(29-54)	91(64-118)	1.31(1.13-1.49)	
15	Andamanese (Indian Ocean)	♀	138(131-146)	54(51-57)	41(31-55)	94(67-120)	1.34(1.08-1.60)	31		Semang (Malaya)	♀	144(134-154)	57(53-61)	33(24-42)	72(53-91)	1.14(0.96-1.32)	
16	Aruba (Yemen)	♂	163(150-175)	64(59-69)	59(48-69)	129(105-153)	1.57(1.41-1.73)	32		Syanjarda	♂	169(157-181)	66(62-71)	67(50-84)	147(111-184)	1.74(1.50-1.98)	

/1/ Body surface area calculated according to the formula $S = 71.84 \times \text{weight}^{0.425} \times \text{height}^{0.725}$, except where otherwise indicated. /2/ Measured by surface integrator. /3/ Measured by coating method.

148. BODY WEIGHTS WITH ORDINARY CLOTHING: MAN, NORTH AMERICA

	Height		Average Body Weights														Desirable Body Weights, >25 yr					
			20-24 yr		25-29 yr		30-34 yr		35-39 yr		40-44 yr		45-49 yr		50-54 yr		55-59 yr		Small Framed		Medium Framed		Large Framed	
	cm	in	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
												Male												
1	149.9	59	53	117	55	122	57	125	58	127	59	130	60	132	60	133	61	134						
2	152.4	60	54	119	56	124	58	127	58	129	60	132	61	134	61	135	62	136						
3	154.9	61	55	121	57	126	59	129	59	131	61	134	62	136	62	137	63	138						
4	157.5	62	56	124	58	128	60	131	60	133	62	136	63	138	63	139	64	140	53-57	116-125	56-60	124-133	59-64	131-142
5	160.0	63	58	127	59	131	61	134	62	136	63	139	64	141	64	142	65	143	54-58	119-128	58-62	127-136	60-65	133-144
6	162.6	64	59	131	61	134	62	137	63	140	64	142	65	144	66	145	66	146	55-60	122-132	59-63	130-140	62-68	137-149
7	165.1	65	61	135	63	138	64	141	65	144	66	146	67	148	68	149	68	150	57-62	126-136	61-65	134-144	64-69	141-153
8	167.6	66	63	139	64	142	66	145	67	148	68	150	69	152	69	153	70	154	58-63	129-139	62-67	137-147	66-71	145-157
9	170.2	67	64	142	66	146	68	149	69	152	70	154	71	156	71	157	72	158	60-65	133-143	64-68	141-151	68-73	149-162
10	172.7	68	66	146	68	150	70	154	71	157	72	159	73	161	73	162	74	163	62-67	136-147	66-71	145-156	69-75	153-166
11	175.3	69	68	150	70	154	72	158	73	162	74	164	75	166	75	167	77	168	63-68	140-151	68-73	149-160	71-77	157-170
12	177.8	70	70	154	72	158	74	163	75	167	77	169	78	171	78	172	79	173	65-70	144-155	69-74	153-164	73-79	161-175
13	180.3	71	72	158	74	163	76	168	78	172	79	175	80	177	81	178	81	179	67-72	148-159	71-76	157-168	75-82	165-180
14	182.9	72	74	163	77	169	79	174	81	178	82	181	83	183	84	185	85	187	69-74	152-164	73-78	161-173	77-84	169-185
15	185.4	73	76	168	79	175	82	180	83	184	85	187	86	190	86	191	86	192	71-77	157-169	75-81	166-178	79-86	174-190
16	188.0	74	78	173	82	181	84	186	86	191	88	194	89	197	89	198	89	199	74-79	163-175	78-83	171-184	81-89	179-196
17	190.5	75	81	178	85	187	87	192	89	197	91	201	92	204	92	205	93	206	76-82	168-180	80-86	176-189	83-92	184-202
												Female												
18	149.9	59	51	113	53	116	54	119	55	122	57	126	58	129	59	131	60	132	47-50	104-111	50-53	110-118	53-58	117-127
19	152.4	60	52	115	54	118	55	121	56	124	58	128	59	131	60	133	61	134	48-51	105-113	51-54	112-120	54-59	119-129
20	154.9	61	53	117	55	120	56	123	57	126	59	130	60	133	61	135	62	137	49-52	107-115	52-55	114-122	55-60	121-131
21	157.5	62	54	120	56	122	57	125	58	129	60	133	61	136	63	138	63	140	50-54	110-118	53-57	117-125	56-61	124-135
22	160.0	63	55	123	57	125	58	128	60	132	62	136	63	139	64	141	64	143	51-55	113-121	54-58	120-128	57-62	127-138
23	162.6	64	57	126	58	129	60	132	62	136	63	139	64	142	65	144	66	146	53-57	116-125	56-60	124-132	59-64	131-142
24	165.1	65	58	129	60	132	62	136	64	140	65	143	66	146	67	148	68	150	54-58	119-128	57-61	127-135	60-65	133-145
25	167.6	66	60	133	62	136	63	140	65	144	67	147	68	151	69	152	70	153	55-60	123-132	58-63	130-140	62-68	138-150
26	170.2	67	62	137	63	140	65	144	67	148	68	151	70	155	71	157	72	158	57-62	126-136	61-65	134-144	64-69	142-154
27	172.7	68	64	141	65	144	67	148	69	152	70	155	72	159	73	162	74	163	58-63	129-139	62-67	137-147	66-71	145-158
28	175.3	69	66	145	67	148	69	152	71	156	72	159	74	163	75	166	76	167	60-65	133-143	64-68	141-151	68-73	149-162
29	177.8	70	68	149	69	152	70	155	72	159	73	162	75	166	77	170	79	173	62-67	136-147	66-70	145-155	69-75	152-166
30	180.3	71	70	153	70	155	72	158	73	162	75	166	77	170	79	174	81	177	63-68	139-150	67-71	148-158	70-77	155-169
31	182.9	72	72	157	72	159	73	162	75	165	77	169	79	173	81	177	83	182						

North Americans of different racial backgrounds, socio-economic conditions, geographical areas, and different periods in American history. Data for the Negro were collected about 1925; White, Cleveland, Ohio, 1920-35; Japanese, 1920-40; Japanese reared in Japan, 1951; Dutch, Finnish, Italian, 1930-40; American Indian, Mexican, 1920-40. Lower economic groups: children of unskilled and semiskilled workers, 16 states in U. S. A., 1937-39; upper economic groups: all occupational groups other than unskilled and semiskilled, 16 states in U. S. A., 1937-39. Unskilled, semiskilled, and managerial, professional: Oregon boys of northwest European ancestry, studied in 1950. Roughly 25% in unskilled and semiskilled category, 49% in the excluded (middle) category, and 26% in the managerial and professional category. Poorest and best residential districts: white girls of Minneapolis, Minn., and Ottawa, Canada, 1930-48. Period 1860-1900 and period 1930-1950: investigations at each age were selected to approximate similar ethnic and socio-economic sampling in the 2 periods. Geographical sections of U. S. A.: about 1935. Values at age 7 are averages of means of ages 6 and 8.

	Specifications	Height, ♂		Height, ♀		Weight, ♂		Weight, ♀	
		cm	in.	cm	in.	kg	lb	kg	lb
1	Birth: Negro	49.6	19.5	48.7	19.1	3.2	7.1	3.1	6.8
2	White	50.8	20.0	50.2	19.7	3.5	7.8	3.4	7.6
3	Period 1860-1900	50.4	19.8						
4	Period 1930-1950	50.7	19.9						
5	2 yr: Japanese	83.8	33.0	82.4	32.4				
6	White	89.6	35.2	85.4	33.6	13.4	29.6	12.5	27.5
7	Period 1860-1900	81.6	32.1						
8	Period 1930-1950	86.9	34.2						
9	7 yr: Dutch	123.3	48.5			22.9	50.4		
10	Finnish	121.2	47.7			23.5	51.7		
11	Indian, American	120.8	47.6	117.0	46.0	21.6	47.5	20.3	44.7
12	Italian	119.3	47.0			22.7	49.9		
13	Japanese			114.1	44.9			20.7	45.6
14	Japanese, reared in Japan	113.9	44.8	112.7	44.4	20.4	44.9	19.7	43.3
15	Mexican			117.0	46.0			21.0	46.2
16	Negro	120.9	47.5	120.4	47.3			22.1	48.6
17	White	122.5	48.2	121.6	47.9	24.0	52.8	23.4	51.6
18	Lower economic groups	σ? 119.3 cm; 47.0 in.				σ? 22.1 kg; 48.6 lb			
19	Upper economic groups	σ? 120.8 cm; 47.6 in.				σ? 22.9 kg; 50.4 lb			
20	Unskilled, semiskilled	121.4	47.8			23.3	51.3		
21	Managerial, professional	123.6	48.7			24.5	53.9		
22	Poorest residential dist.			118.9	46.8			21.4	47.1
23	Best residential dist.			122.0	48.0			22.8	50.2
24	Period 1860-1900	114.3	45.0						
25	Period 1930-1950	119.6	47.1	118.4	46.6	22.9	50.4	22.5	49.5
26	Northeastern USA	120.0	47.2	118.9	46.8	22.7	49.9	22.2	48.8
27	Northcentral USA	118.9	46.8	118.1	46.5	22.2	48.8	21.4	47.1
28	Southcentral USA	118.6	46.7	118.9	46.8	21.9	48.2	21.4	47.1
29	Western USA			118.9	46.8			21.4	47.1
30	10 yr: Indian, American			131.7	51.8			27.3	60.1
31	Japanese			129.6	51.0			27.8	61.2
32	Japanese, reared in Japan	127.6	50.2	127.3	50.1	26.4	58.1	26.1	57.4
33	Mexican			132.2	52.0			28.2	62.0
34	Negro	135.3	53.2	135.2	53.1			30.7	67.5
35	White	137.9	54.3	137.7	54.2	32.0	70.7	31.8	70.3
36	Lower economic groups	σ? 135.0 cm; 53.1 in.				σ? 29.7 kg; 65.3 lb			
37	Upper economic groups	σ? 136.6 cm; 53.8 in.				σ? 31.1 kg; 68.4 lb			
38	Unskilled, semiskilled	137.8	54.3			32.3	71.1		
39	Managerial, professional	140.7	55.4			34.3	75.5		
40	Poorest residential dist.			134.3	52.9			29.0	63.8
41	Best residential dist.			138.7	54.6			31.8	70.0

	Specifications	Height, ♂		Height, ♀		Weight, ♂		Weight, ♀	
		cm	in.	cm	in.	kg	lb	kg	lb
42	10 yr: Period 1860-1900	129.6	51.0						
43	Period 1930-1950	139.2	54.8						
44	Northeastern USA	135.1	53.2	135.1	53.2	30.5	67.1	30.3	66.7
45	Northcentral USA	135.4	53.3	134.4	52.9	30.5	67.1	30.1	66.2
46	Southcentral USA	134.9	53.1	134.1	52.8	30.2	66.4	29.3	64.5
47	Western USA	134.9	53.1	134.6	53.0	29.6	65.1	28.6	62.9
48	11 yr: Dutch	144.3	56.8			33.8	74.4		
49	Finnish	141.6	55.7			33.4	73.5		
50	Indian, American	138.9	54.7			30.3	66.7		
51	Italian	139.1	54.8			32.1	70.6		
52	Japanese, reared in Japan	132.1	52.0	132.5	52.2	28.8	63.4	29.2	64.2
53	Mexican	138.2	54.8						
54	Negro	140.9	55.4	141.2	55.5				
55	White	142.7	56.2	143.5	56.5	35.2	77.6	35.8	79.0
56	14 yr: Indian, American			150.8	59.4			42.8	94.2
57	Japanese			150.6	59.3			43.3	95.3
58	Japanese, reared in Japan	148.4	58.4	146.7	57.8	40.5	89.1	41.2	90.6
59	Mexican			152.0	59.8			44.5	97.9
60	Negro	156.5	61.5	154.7	60.8	48.0	105.8	47.7	105.2
61	White	160.0	63.0	158.2	62.3	48.9	107.9	49.1	108.5
62	Period 1860-1900	151.8	59.8						
63	Period 1930-1950	163.7	64.4						
64	Northeastern USA	155.4	61.2	155.7	61.3	45.2	99.4	48.1	105.8
65	Northcentral USA	155.7	61.3	155.2	61.1	45.8	100.8	46.5	102.3
66	Southcentral USA	155.7	61.3	155.4	61.2	44.6	98.1	45.2	99.4
67	Western USA	153.2	60.3	153.9	60.6	41.27	90.69	45.7	100.5
68	15 yr: Dutch	168.6	66.4					50.5	111.1
69	Finnish	164.4	64.7					52.1	114.6
70	Indian, American	160.5	63.2					45.2	99.4
71	Italian	161.4	63.5					50.9	112.0
72	16 yr: Japanese, reared in Japan	157.7	62.1	150.3	59.2			49.1	108.0
73	Negro	161.0	63.3	158.1	62.1			53.0	116.9
74	White	166.6	65.6	160.5	63.2			55.1	121.7
75	19 yr: Japanese, reared in Japan	161.1	63.4	150.7	59.2				
76	Negro	172.9	67.9	159.9	62.8			68.1	150.2
77	White	173.8	68.3	164.6	64.7			68.5	151.2
78	Period 1860-1900	172.1	67.8						
79	Period 1930-1950	175.6	69.1						
80	25 yr: Japanese, reared in Japan	161.8	63.7	150.4	59.2				
81	Period 1860-1900	171.8	67.6						
82	Period 1930-1950	173.5	68.3						

Data are from surveys conducted over the past 25 or more years. Values in parentheses are ranges and correspond to estimate "b" of the 95% range (cf Introduction).

	Specifications		Height, Male		Height, Female		Weight, Male		Weight, Female	
			cm	in	cm	in	kg	lb	kg	lb
1	Birth:	USA White	50, 8(46, 8-54, 8)	19, 9(18, 4-21, 5)	50, 2(46, 4-54, 1)	19, 7(18, 2-21, 2)	3, 5(2, 2-4, 9)	7, 8(4, 9-10, 7)	3, 4(2, 5-4, 4)	7, 6(5, 5-9, 6)
2		USA Negro	49, 6	19, 5	48, 7	19, 1	3, 2(3, 0-3, 4)	7, 1(6, 6-7, 4)	3, 1(2, 9-3, 3)	6, 8(6, 4-7, 3)
3		African Pygmy	45, 9	18, 0	46, 4	18, 2	3, 6	7, 9	3, 7	8, 2
4		British	51, 2	20, 1	50, 8	20, 0	3, 4	7, 4	3, 3	7, 3
5		Chinese	48, 2	18, 9	48, 2	18, 9	3, 1	6, 8	3, 0	6, 6
6		Danish					3, 4	7, 5	3, 3	7, 3
7		French	49, 9	19, 6	49, 2	19, 3	3, 1	6, 8	3, 1	6, 8
8		German	51, 0	20, 0	50, 5	19, 8	3, 5	7, 7	3, 3	7, 3
9		Japanese	50, 2	19, 7	49, 3	19, 4	3, 05	6, 72	2, 97	6, 54
10		Russian	48, 6	19, 1	48, 6	19, 1	3, 4	7, 5	3, 3	7, 3
11		Swiss	50, 8	20, 0	50, 2	19, 7	3, 3	7, 3	3, 1	6, 8
12	1 yr:	USA White	75, 2(67, 3-83, 1)	29, 6(26, 5-32, 7)	75, 4(66, 5-84, 3)	29, 6(26, 1-33, 1)	10, 9(7, 0-14, 8)	24, 0(15, 4-32, 6)	10, 3(7, 9-12, 6)	22, 6(17, 4-27, 8)
13		USA Negro	74, 9(62, 1-87, 7)	29, 4(24, 4-34, 5)	83, 7	32, 9	8, 6(6, 5-10, 6)	19, 0(14, 3-23, 4)	8, 6(6, 1-11, 0)	19, 0(13, 4-24, 2)
14		African Pygmy	71, 0	27, 9	65, 0	25, 5			7, 0	15, 4
15		Chinese	76	29, 9	75	29, 5	10, 2	22, 5	9, 8	21, 6
16		British	70, 8	27, 8	69, 8	27, 4	9, 3	20, 5	8, 8	19, 4
17		Chinese	73, 5	28, 9	71, 4	28, 1				
18		German	75, 0	29, 5	74, 5	29, 3	9, 7	21, 4	9, 5	20, 9
19		Japanese	76, 4	30, 1	75, 6	30, 0	9, 7	21, 4	9, 3	20, 5
20	2 yr:	USA White	89, 6(82, 4-96, 8)	35, 2(32, 4-38, 0)	88, 4(78, 8-91, 9)	33, 6(31, 0-36, 1)	13, 4(10, 6-16, 3)	29, 6(23, 4-35, 8)	12, 5(10, 3-14, 7)	27, 5(22, 6-32, 4)
21		USA Negro	89, 1(77, 6-100, 6)	35, 0(30, 5-39, 5)	88, 9(77, 8-99, 0)	33, 8(29, 6-38, 9)				
22		Canadian	88, 1	34, 7	85, 3	33, 6	13, 6	30, 0	12, 7	28, 0
23	3 yr:	USA White	96, 8(89, 3-104, 4)	38, 0(35, 1-41, 0)	95, 9(87, 5-104, 3)	37, 7(34, 4-41, 0)	15, 3(12, 7-17, 8)	33, 7(28, 1-39, 3)	15, 1(11, 1-19, 2)	33, 4(24, 4-42, 3)
24		USA Negro	95, 2(83, 4-107, 0)	37, 4(32, 8-42, 1)	95, 8(86, 6-105, 0)	37, 7(34, 0-41, 3)				
25		African Pygmy	88, 6	34, 8						
26		Austrian	95	36, 9	94	36, 2	14, 5	32, 0	14, 0	30, 9
27		British	96, 3	37, 8	96, 0	37, 7	13, 7	30, 2	13, 2	29, 1
28		Canadian	93, 0	36, 6	91, 4	36, 0	14, 5	32	14, 0	31
29		Chinese	92, 0	36, 2	89, 7	35, 1				
30		Czechoslovakian	89, 7	35, 3	87, 7	34, 5				
31		German	93, 0	36, 5	92, 5	36, 4	14, 1	31, 1	13, 7	30, 2
32		Japanese	91, 5	36, 0	89, 7	35, 1	13, 6	30, 0	13, 2	29, 1
33	4 yr:	USA White	103, 9(94, 5-113, 3)	40, 9(37, 2-44, 6)	103, 9(94, 5-113, 3)	40, 9(37, 2-44, 6)	17, 3(13, 3-21, 3)	38, 2(29, 4-47, 0)	16, 9(12, 6-21, 2)	37, 3(27, 9-46, 7)
34		USA Negro	102, 0(90, 9-113, 1)	40, 1(35, 7-44, 4)	100, 6(88, 3-112, 9)	39, 5(34, 7-44, 4)				
35		Canadian	99, 6	39, 2	96	37, 8	16, 8	37	16, 3	36
36		Japanese	98, 3	38, 7	97, 1	38, 2	15, 3	33, 7	14, 7	32, 4
37	5 yr:	USA White	111, 5(101, 6-121, 4)	43, 9(40, 0-47, 8)	110, 7(100, 8-120, 7)	43, 6(39, 7-47, 5)	19, 6(14, 7-24, 5)	43, 2(32, 4-54, 0)	19, 0(13, 8-24, 3)	42, 0(30, 4-53, 6)
38		USA Negro	110, 0(98, 9-121, 1)	43, 2(38, 9-47, 6)	109, 9(98, 7-121, 1)	43, 2(38, 8-47, 6)				
39		African Pygmy	100, 4	39, 5	98, 1	38, 6	13, 5	29, 7	13, 5	29, 7
40		Austrian	108	42, 4	107	42, 1	18, 5	40, 8	18, 0	39, 7
41		British	108, 2	42, 5	107, 9	42, 4	15, 5	34, 2	15, 9	35, 0
42		Canadian	106, 4	41, 9	106, 2	41, 8	18, 1	40	18, 6	41
43		Chinese	104, 4	41, 0	108, 0	42, 4	14, 9	32, 8	14, 0	30, 9
44		Czechoslovakian	103, 5	40, 7	102, 7	40, 4	20, 5	45, 2	19, 1	42, 1
45		French	107, 9	42, 4	106, 9	42, 0	18, 4	40, 6	17, 8	39, 2
46		German	107, 0	42, 1	106, 5	41, 9	18, 6	41, 0	17, 8	39, 2
47		Japanese	104, 0	40, 1	103, 3	40, 7	16, 9	36, 8	16, 2	35, 7
48	6 yr:	USA White	117, 1(106, 7-127, 5)	46, 1(42, 0-50, 2)	116, 3(105, 9-126, 7)	45, 8(41, 7-49, 9)	21, 6(15, 9-27, 2)	47, 6(35, 2-60, 0)	21, 0(15, 0-27, 0)	46, 4(33, 1-59, 7)
49		USA Negro	116, 0(103, 8-128, 2)	45, 6(40, 8-50, 4)	116, 2(103, 5-128, 9)	45, 7(40, 7-50, 7)				
50		Canadian	113, 3	44, 6	112, 3	44, 2	20, 8	46	19, 9	44
51		Japanese	109, 3	43, 0	108, 3	42, 6	18, 4	40, 6	17, 5	38, 6
52	7 yr:	USA White	122, 4(11, 5-133, 4)	48, 2(43, 9-52, 5)	121, 7(110, 7-132, 6)	47, 9(43, 6-52, 2)	23, 8(17, 5-30, 1)	52, 5(38, 6-66, 4)	23, 2(16, 5-29, 9)	51, 2(36, 5-65, 9)
53		USA Negro	120, 3(108, 9-131, 7)	47, 3(42, 8-51, 8)	120, 8(105, 7-135, 9)	47, 5(41, 5-53, 4)				
54		African Pygmy	103, 9	40, 8	102, 8	40, 4	17, 6	38, 8		
55		Austrian	119	46, 8	118	46, 4	22, 5	49, 6	22, 0	48, 5
56		British	118, 1	46, 4	117, 9	46, 3	19, 8	43, 6	19, 3	42, 5
57		Canadian	119, 4	47, 0	118, 1	46, 5	22, 7	50	22, 2	49
58		Chinese	114, 6	45, 0	117, 2	46, 1	18, 4	40, 6	20, 1	44, 3
59		Czechoslovakian	115, 6	45, 4	115, 0	45, 2	24, 3	53, 6	23, 3	51, 4
60		Danish	118, 5	46, 5	117, 9	46, 3	21, 8	48, 0	21, 5	47, 4

	French	117, 7	46. 3	116, 4	45, 7	22, 2	48, 9	21. 2	46. 7
	German	119, 5	47, 0	118, 5	46, 6	22, 2	48, 9	21, 6	47, 6
	Japanese	114, 4	45.0	113, 5	44. 7	20, 3	44, 7	19, 5	43, 0
	Spanish	117	46, 0	116	45, 6	21, 6	47, 6	21, 5	47, 4
	Swiss	120	47, 2	119, 0	46, 8	22, 2	48, 9	21, 6	47, 6
8 yr:	USA White	128, 0(116, 6-139, 4)	50, 4(45, 9-54, 9)	127, 0(115, 6-138, 4)	50, 0(45, 5-54, 5)	26, 4(18, 6-34, 1)	58, 2(41, 1-75, 3)	25, 8(17, 4-34, 1)	56, 9(38, 5-75, 3)
	USA Negro	125, 8(113, 3-138, 3)	49, 4(44, 5-54, 4)	124, 6(111, 0-138, 2)	49, 0(43, 6-54, 3)				
	Canadian	124, 7	49, 1	124, 2	48, 9	25, 8	57	25, 8	57
	Japanese	118, 5	46, 7	118, 6	46, 7	22, 3	49, 1	21, 9	48, 2
9 yr:	USA White	133, 1(121, 2-144, 8)	52, 4(47, 7-57, 1)	132, 1(120, 1-144, 0)	52, 0(47, 3-56, 7)	29, 2(20, 5-37, 9)	64, 4(45, 2-83, 6)	28, 5(18, 7-38, 4)	63, 0(41, 2-84, 8)
	USA Negro	130, 8(118, 5-143, 1)	51, 4(46, 6-56, 2)	131, 3(118, 7-143, 9)	51, 6(46, 7-56, 6)				
	African Pygmy	113, 3	44, 5	113, 0	44, 0				
	Argentinian	123	48, 3	122	47, 9	28, 1	61, 9	27, 6	60, 8
	Austrian	128	50. 3	127	49, 9	26, 7	58, 8	26, 0	57, 3
	British	128, 0	50, 3	127, 8	50, 2	23, 4	51. 6	22, 0	48, 4
	Canadian	130, 3	51, 3	129, 5	51, 0	28, 5	63	28, 1	62
	Chinese	123, 7	48, 6	126, 6	49, 8	22, 2	48, 9	23, 4	51, 6
	Czechoslovakian	126, 6	49, 5	125, 9	49, 1	28, 1	61, 9	27, 8	61, 3
	Danish	127, 9	50, 3	127, 5	50, 1	26, 2	57, 7	26, 2	57, 7
	French	127, 9	50, 3	127, 7	50, 2	27, 0	59, 5	26, 8	59, 1
	German	129, 0	50, 7	128, 5	50, 5	26, 7	58, 8	25, 9	57, 1
	Japanese	124, 1	48, 9	123, 6	48, 7	24, 7	54, 4	23, 8	52, 5
	Russian	125, 3	49, 2	124, 5	48, 9				
	Spanish	123	48, 3	124, 6	49, 0	24, 7	54, 4	26, 0	57, 3
	Swiss	129	50, 7	129, 1	50, 7	26, 3	58, 0	26, 2	57, 7
10 yr:	USA White	137, 9(125, 5-150, 4)	54, 3(49, 4-59, 2)	137, 7(124, 7-150, 6)	54, 2(49, 1-59, 3)	32, 0(21, 8-42, 2)	70, 7(48, 2-93, 2)	31, 8(20, 1-43, 6)	70, 3(44, 4-96, 2)
	USA Negro	135, 3(121, 6-149, 0)	53, 2(47, 8-58, 6)	135, 2(120, 4-150, 0)	53, 1(47, 3-58, 9)				
	Canadian	135, 9	53, 5	134, 4	53, 3	31, 7	70	31, 3	69
	Japanese	128, 9	50, 7	128, 6	50, 6	26, 9	59, 2	26, 5	58, 3
11 yr:	USA White	142, 7(129, 8-155, 7)	56, 2(51, 1-61, 3)	143, 5(129, 5-157, 5)	56, 5(51, 0-62, 0)	35, 2(23, 5-46, 8)	77, 6(51, 9-103, 3)	35, 8(22, 0-49, 6)	79, 0(48, 6-109, 4)
	USA Negro	140, 9(129, 0-152, 8)	55, 4(50, 7-60, 1)	141, 2(124, 1-158, 3)	55, 5(48, 8-62, 2)				
	African Pygmy					23, 0	50, 7	18, 5	40, 8
	Argentinian	132	51, 9	132	51, 9	33, 1	73, 0	33, 9	74, 7
	Austrian	137	53, 8	138	54, 2	31, 8	70, 1	31, 5	69, 4
	British	136, 7	53, 7	137, 9	54, 2	26, 8	59, 1	27, 2	59, 9
	Canadian	140, 7	55, 4	140, 5	55, 3	34, 9	77	34, 9	77
	Chinese	131, 3	51, 6	135, 4	53, 2	26, 5	58, 4	28, 7	63, 3
	Czechoslovakian	133, 4	52, 4	133, 4	52, 4	32, 0	70, 5	33, 6	74, 1
	Danish	137, 5	54, 0	137, 5	54, 0	31, 8	70, 1	32, 3	71, 2
	French	137, 8	54, 2	138, 6	54, 5	32, 6	71, 9	33, 9	74, 7
	German	137, 5	54, 0	139, 0	54, 6	31, 5	69, 4	31, 4	69, 2
	Japanese	132, 9	52, 2	134, 0	52, 8	29, 3	64, 6	29, 8	65, 7
	Spanish	132, 7	52, 2	134	52, 7	29, 0	63, 9	31, 5	69, 4
	Swiss	138	54, 2	137, 3	54, 0	30, 8	67, 9	30, 9	68, 1
12 yr:	USA White	147, 8(133, 4-162, 3)	58, 2(52, 5-63, 9)	147, 9(135, 8-164, 3)	60, 0(53, 3-64, 7)	39, 9(24, 7-52, 8)	85, 6(54, 6-116, 6)	40, 5(24, 8-56, 4)	89, 1(54, 8-124, 6)
	USA Negro	144, 8(129, 2-160, 4)	56, 9(50, 8-63, 0)	149, 0(136, 3-161, 7)	58, 6(53, 6-63, 5)	37, 0(26, 8-47, 2)	81, 6(59, 1-104, 0)	39, 9(34, 8-45, 0)	88, 1(76, 7-99, 2)
	Canadian	145, 8	57, 4	147, 8	58, 2	38, 1	84	41, 7	92
	Japanese	137, 7	54, 2	139, 5	54, 9	32, 6	70, 6	33, 6	74, 1
13 yr:	USA White	153, 7(137, 7-169, 7)	60, 5(54, 2-66, 8)	153, 9(141, 0-166, 9)	60, 6(55, 5-65, 7)	43, 3(27, 1-59, 5)	95, 6(59, 9-131, 3)	45, 4(29, 4-61, 4)	100, 3(65, 0-135, 6)
	USA Negro	150, 1(133, 0-166, 3)	59, 0(52, 6-65, 4)	153, 7(137, 5-169, 9)	60, 4(54, 0-66, 8)	43, 9(34, 5-53, 3)	96, 7(76, 0-117, 5)	43, 8(23, 2-64, 4)	96, 7(51, 1-142, 0)
	African Pygmy	115, 1	45, 2						
	Argentinian	142	55, 8	145	57, 0	40, 6	89, 5	41, 9	92, 3
	Austrian	148	58, 2	149	58, 6	38, 5	84, 9	38, 5	84, 9
	British	155, 1(136, 9-173, 5)	61, 1(53, 9-68, 3)	154, 4(141, 0-167, 6)	60, 8(55, 5-68, 0)	42, 7(26, 8-58, 7)	94, 3(59, 1-129, 5)	45, 1(31, 1-59, 1)	99, 6(68, 7-130, 5)
	Canadian	150, 6	59, 3	153, 4	60, 4	42, 6	94	46, 3	102
	Chinese	141, 1	55, 4	145, 7	57, 3	32, 3	71, 2	37, 0	81, 5
	Czechoslovakian	142, 9	56, 2	144, 7	56, 9	34, 3	75, 6	35, 0	77, 1
	Danish	146, 5	57, 6	148, 6	58, 4	38, 1	84, 0	40, 8	89, 9
	German	147, 0	57, 8	151, 0	59, 3	37, 5	82, 7	40, 2	88, 6
	Japanese	142, 6	56, 1	144, 4	56, 9	35, 6	78, 5	38, 2	84, 2
	Spanish	139, 6	54, 9	143, 7	56, 5	35, 7	78, 7	38, 0	83, 8
14 yr:	USA White	160, 0(143, 0-177, 0)	63, 0(56, 3-69, 7)	158, 2(146, 3-170, 2)	62, 3(57, 6-67, 0)	48, 9(31, 0-66, 7)	107, 9(68, 5-147, 3)	49, 1(33, 9-64, 4)	108, 5(74, 8-142, 2)
	USA Negro	156, 5(140, 0-172, 9)	61, 5(55, 1-67, 9)	154, 7(140, 5-168, 9)	60, 8(55, 2-66, 4)	48, 0(38, 6-57, 4)	105, 8(85, 1-126, 5)	47, 7(27, 1-68, 3)	105, 2(59, 7-150, 5)
	British	155, 1(136, 9-173, 5)	61, 1(53, 9-68, 3)	154, 4(141, 0-167, 6)	60, 8(55, 5-66, 0)	42, 7(26, 8-58, 7)	94, 3(59, 1-129, 5)	45, 1(31, 1-59, 1)	99, 6(68, 7-130, 5)
	Canadian	158, 0	62, 2	155, 7	61, 3	48, 9	108	48, 5	107
	Japanese	149, 7	58, 9	147, 5	58, 1	41, 1	90, 6	41, 5	91, 4

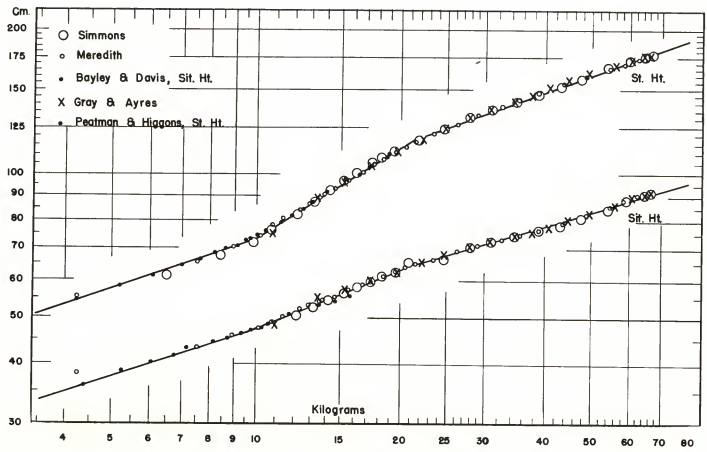
150. HEIGHT AND WEIGHT: MAN, VARIOUS NATIONALITIES (Concluded)

Data are from surveys conducted over the past 25 or more years. Values in parentheses are ranges and correspond to estimate "B" of the 95% range (of introduction).

	Specifications	Height, Male		Height, Female		Weight, Male		Weight, Female	
		cm	in	cm	in	kg	lb	kg	lb
127	15 yr: USA White	166.6(151.1-182.1)	65.6(59.5-71.7)	160.5(149.1-172.0)	63.2(58.7-67.7)	55.1(36.8-73.4)	121.7(81.3-162.1)	52.1(37.7-66.5)	115.0(83.2-146.8)
128	USA Negro	161.0(145.8-176.2)	63.3(57.3-69.2)	158.1(146.6-169.6)	62.1(57.6-66.6)	53.0(41.6-64.4)	116.9(91.7-141.9)	53.0(28.3-77.7)	116.9(62.4-171.3)
129	British	158.6(140.2-177.0)	62.4(55.2-69.7)	155.8(144.0-167.9)	61.4(56.7-66.1)	45.8(28.6-63.0)	101.1(63.2-139.0)	47.7(32.6-62.7)	105.2(72.0-138.4)
130	Canadian	164.3	64.7	158.0	62.2	53.9	119	50.7	112
131	Czechoslovakian	156	61.3			52.1	114.8		
132	Danish	160.1	62.9	158.0	62.1	49.2	108.4	49.6	109.3
133	German	160.5	63.1	160.0	62.9	48.1	106.0	49.5	109.1
134	16 yr: USA White	170.9(157.0-184.9)	67.3(61.8-72.8)	161.3(150.4-172.2)	63.5(59.2-67.8)	59.8(43.0-76.5)	131.9(94.9-168.9)	53.3(39.1-67.4)	117.6(86.4-148.8)
135	USA Negro	163.6(149.0-178.2)	64.3(58.6-70.0)	157.8(146.4-169.2)	62.0(57.5-66.5)	57.0(45.8-68.2)	125.7(100.9-150.3)	56.9(32.6-81.2)	125.7(71.9-179.0)
136	USA Negro	163.9(146.1-181.6)	64.5(57.5-71.5)	157.6(145.0-170.0)	62.0(57.1-66.9)	50.6(33.3-67.9)	111.7(73.5-149.9)	49.8(35.7-64.0)	110.0(78.7-141.3)
137	Canadian[1]	169.4	66.7	158.7	62.5	61.6	136	54.4	120
138	Japanese	158.9	62.6	150.7	59.3	49.9	110.0	47.7	105.1
139	17 yr: USA White	172.1(159.5-184.7)	67.6(62.7-72.6)	161.5(150.6-172.5)	63.6(59.3-67.9)	63.6(49.2-78.0)	140.4(108.6-172.2)	53.9(40.1-67.7)	119.0(88.6-149.4)
140	USA Negro	167.2(157.3-183.0)	66.9(61.8-71.9)	158.5(145.8-171.2)	62.3(57.3-67.3)	63.8(48.6-79.1)	140.9(107.2-174.6)		
141	British	167.4(152.1-182.6)	65.9(59.9-71.9)	157.8(146.0-169.7)	62.1(57.5-66.8)	54.4(39.3-69.4)	120.0(86.7-153.3)	51.1(37.3-64.9)	112.8(82.4-143.2)
142	Chinese	162.4	63.8	154.3	60.6	48.3	106.5	47.5	104.7
143	Czechoslovakian	159	62.5			61.3	135.1		
144	German	170.5	67.0	164.0	64.5	59.8	131.8	56.3	124.1
145	18 yr: USA White	173.5(161.1-185.8)	68.3(63.3-73.0)	163.7(156.0-171.4)	64.3(61.3-67.4)	67.0(50.3-83.6)	147.8(111.1-184.6)	57.4(46.0-68.8)	125.6(101.3-151.5)
146	USA Negro	173.4(158.5-188.2)	68.1(62.3-74.0)	159.2(148.1-170.3)	62.6(58.2-66.9)	67.0(53.0-81.0)	147.8(116.9-178.7)		
147	British	168.4(153.7-183.1)	66.3(60.5-72.1)	157.9(145.5-170.4)	62.2(57.3-67.1)	56.4(41.5-71.3)	124.5(91.7-157.3)	51.8(37.5-66.1)	114.4(82.8-146.0)
148	Canadian[2]	172.7	68.0	159.0	62.6	65.2	144	56.2	124
149	Japanese	161.2	63.5	151.7	59.7	53.5	117.9	49.6	109.3
150	19 yr: USA White	173.8(161.4-186.3)	68.3(63.4-73.2)	164.6(155.5-173.7)	64.7(61.1-68.3)	68.5(51.4-85.5)	151.2(113.6-188.8)	58.2(48.9-67.4)	128.0(107.8-148.6)
151	USA Negro	172.9(160.1-185.6)	67.9(62.7 73.0)	159.9(147.2-172.6)	62.8(57.8-67.8)	68.1(53.0-83.1)	150.2(117.0-183.4)		
152	British	169.5(155.2-183.6)	66.7(61.1-72.3)	158.2(147.1-169.4)	62.3(57.9-66.7)	57.9(43.2-72.6)	127.8(95.4-160.2)	52.5(38.3-66.8)	116.0(84.6-147.4)
153	Chinese	165.0	64.8	152.0	59.7	52.6	115.9	44.4	97.9
154	German	174.0	68.4	165.0	64.8	64.5	142.2	59.0	130.0
155	20-24 yr: USA White	174.2(161.6-186.5)	68.6(63.5-73.3)	161.5	63.6	70.0(52.2-88.0)	154.7(115.2-194.2)	55.7	123.0
156	USA Negro	173.1(160.4-185.8)	68.0(63.0-73.0)	159.4(145.0-173.8)	62.6(57.0-68.3)	69.7(53.4-85.9)	153.8(118.0-189.7)		
157	British	170.2(156.7-183.7)	67.0(61.7-72.3)	158.3(146.7-170.0)	62.3(57.8-66.9)	60.6(45.8-75.4)	133.8(101.1-166.6)	53.0(38.2-68.0)	117.1(84.2-150.0)
158	Canadian	172.5	67.9	159.5	62.8	69.8	154	56.2	124
159	Chinese[4]	166.0	65.2	156.0	61.3	53.8	118.6	49.0	108.0
160	German[3]	167.0	65.7	157.4	61.9	59.5	131.1	53.2	117.3
161	Japanese[5]	162.4	63.9	150.8	59.3	56.2	123.9	49.0	108.0
162	25-29 yr: USA White	173.7(161.7-186.1)	68.3(63.6-73.1)	161.0	63.4	71.5(53.4-89.5)	157.8(117.9-197.6)	56.5	124.7
163	USA Negro	173.0(160.7-185.4)	68.0(63.1-72.8)	158.7(142.1-175.3)	62.4(55.8-68.9)	70.7(52.8-88.5)	156.0(116.5-195.4)		
164	British	169.6(156.5-182.6)	66.8(61.6-71.9)	157.8(145.9-170.7)	62.1(57.1-67.2)	61.7(46.4-77.1)	136.3(102.4-170.2)	53.1(37.3-69.0)	117.3(82.3-152.3)
165	Canadian	173.5	68.3	159.2	62.7	72.5	160	57.1	126
166	German[3]	168.2	66.1	157.8	62.0	66.2	145.9	54.8	120.8
167	Japanese	162.1	63.8	150.4	59.2	55.1	121.4	48.3	106.5
168	30-34 yr: USA White	173.3(161.1-185.6)	68.2(63.4-73.3)	161.0	63.4	71.6(53.4-89.9)	158.1(117.8-198.4)	58.7	129.5
169	British	169.5(156.5-182.6)	66.7(61.6-71.9)	157.5(145.3-169.7)	62.0(57.2-66.8)	62.7(46.2-79.2)	138.4(102.0-174.8)	54.2(36.6-71.8)	119.6(80.8-158.4)
170	Canadian	172.7	68.0	159.5	62.8	75.7	167	58.9	130
171	German[3]	168.6	66.3	158.0	62.1	66.1	145.7	55.3	121.9
172	30-39 yr: USA Negro	170.0(157.9-182.1)	66.8(62.1-71.6)	158.8(146.2-171.4)	62.4(57.5-67.4)	71.9(52.4-91.3)[7]	158.6(115.7-201.5)[7]		
173	31-40 yr: Japanese	160.4	63.1	149.3	58.8	54.7	120.6	48.2	106.2
174	35-44 yr: USA White			160.3	63.1			62.5	138.0
175	British	168.6(154.8-182.4)	66.4(61.0-71.8)	156.8(144.2-169.6)	61.7(56.8-66.7)	62.6(45.5-79.6)	138.1(100.4-175.8)	56.2(36.0-76.4)	124.0(79.5-168.7)
176	Canadian	171.5	67.5	158.5	62.4	75.7	167	61.2	135
177	40 yr: German	168.6	66.3	158.0	62.1				
178	40-49 yr: USA Negro	170.6(157.9-183.3)	67.0(62.1-72.0)	158.7(147.3-170.1)	62.3(57.9-66.8)				
179	41-50 yr: Japanese	159.2	62.7	147.8	58.2	54.6	120.5	48.0	105.8
180	45-54 yr: USA White			159.4	62.8			67.0	147.8
181	British	167.2(154.0-180.2)	65.8(60.6-71.0)	155.8(143.3-168.5)	61.4(56.4-66.4)	62.2(43.9-80.5)	137.2(96.8-177.7)	58.6(35.8-81.4)	129.2(78.9-179.6)
182	Canadian	169.9	66.9	157.0	61.8	74.3	164	65.2	144
183	55-64 yr: USA White			158.0	62.2			65.5	144.5
184	British	166.5(152.8-178.9)	65.3(60.2-70.5)	154.5(141.5-167.6)	60.8(55.7-66.0)	62.2(43.0-81.2)	137.2(94.8-179.5)	58.2(34.8-82.0)	128.5(76.9-180.0)
185	Canadian	167.6	66.0	155.7	61.3	72.9	161	66.6	147
186	>64 yr: USA White			156.6	61.7			62.7	138.5
187	British	163.5(147.1-179.9)	64.4(57.9-70.8)	152.7(140.6-164.9)	60.1(55.3-64.9)	60.1(40.8-79.3)	132.6(90.2-175.0)	54.3(34.7-73.9)	119.9(76.7-163.2)
188	Canadian	166.4	65.5	153.9	60.6	70.2	155	62.5	138

[1] 16 and 17 yr. [2] 18 and 19 yr. [3] 21 yr. [4] 20 yr. [5] 25 yr. [6] 30 yr. [7] 30-34 yr.

These graphs are based on five large groups of measurements on males from infancy to old age. The five groups as listed in the upper left corner of the chart, contain 6,704, 16,510, 469, 3,097, and 2,638 values, respectively. The standing height curve is based on a total of 17,523 values; that for sitting height, on 14,992 values. In each of the five groups care was taken to exclude persons not in good health. Curves representing ordinary range limits (95% range) are not available, but would be expected to lie above and below each of these curves and parallel to it. The upper of such curves for standing height would represent the ordinarily encountered limit in the direction of slenderness, the lower the ordinarily encountered limit in the direction of heaviness of build. Evidence indicates that curves for females (not represented) are identical in slope and position with these for males. The means for males simply lie farther to the right along the curve than do the means for females of the same age. The line slopes for the standing height curve are 0.34, 0.63, and 0.35, with the breaks at 10 kg and 22 kg. For sitting height the comparable slopes are 0.34, 0.41, and 0.30. The relationships between standing height and weight for the three weight ranges are expressed by the formulae, $H/W^{0.34}$, $H/W^{0.63}$, and $H/W^{0.35}$.



Animals in wild state are indicated by an asterisk (*). When no symbol (♂, ♀) precedes value, sex of animal is unspecified.

	Species	Recorded Life Span	
		Av yr	Max yr
	Vertebrata		
	Mammalia		
1	Agouti (Dasyprocta aguti)	6	>10
2	Alpaca (Lama pacos)	12	>17
3	Anteater, spiny (Tachyglossus aculeatus)		50[1]
4	Antelope, pronghorned (Antilocapra americana)	8	15
5	Ape, black (Cynopithecus niger)*	2	18
6	Ass, African wild (Equus asinus taeniopus)	14.6	19.3
7	Baboon, sacred (Papio hamadryas)	15	♀24
8	Badger, American (Taxidea taxus)	11	>13
9	Bat, American brown (Eptesicus fuscus)		19
10	Bear, brown (Ursus arctos)		34
11	Bear, grizzly (U. horribilis)	20	>31
12	Bear, polar (Thalarctos maritimus)	16	33
13	Beaver, American (Castor canadensis)		♀19
14	Blackbuck (Antilope cervicapra)	7	♂15
15	Buffalo, American (Bison bison)	10	♀>22
16	Buffalo, African (Syncerus caffer)	10	>15
17	Camel, dromedary (Camelus dromedarius)		>25
18	Cat, domestic (Felis catus)	13-17	21
19	Cheetah (Acinonyx jubatus)	6	>15
20	Chimpanzee (Pan troglodytes)	15-20	37
21	Chinchilla (Chinchilla laniger)	4	7
22	Chipmunk, eastern (Tamias striatus)	2.5	>7
23	Civet (Viverra spp)		>15
24	Coyote (Canis latrans)	9	14
25	Deer, fallow (Dama dama)	10	15
26	Dingo (Canis dingo)	3	♀>12
27	Dog, domestic (C. familiaris)	13-17	34
28	Dolphin (Delphinus delphis)	25-30	
29	Dormouse, garden (Eliomys quercinus)	2-3	>5
30	Elephant, African (Loxodonta africana)	24	36
31	Elephant, Indian (Elephas maximus)		57
32	Elk, European (Alces alces)	15-20	25
33	Fox, arctic (Alopex lagopus)	8	14
34	Fox, red (Vulpes fulva)		12
35	Gazelle, Korin (Gazella rufifrons)		♂11
36	Genet (Genetta genetta)	>7	12.5
37	Gibbon (Hylobates spp)		>23
38	Giraffe (Giraffa camelopardalis)	14	>28
39	Gnu, brindled (Connochaetes taurinus)		16
40	Goat (Capra hircus)	8-10	18
41	Gorilla (Gorilla gorilla)		>7
42	Guinea pig (Cavia porcellus)	>2	>6
43	Hamster, common (Cricetus cricetus)	2	2.5
44	Hamster, golden (Mesocricetus auratus)	1	1.8
45	Hedgehog, European (Erinaceus europaeus)		2
46	Hippopotamus (Hippopotamus amphibius)	40	49[2]
47	Horse, domestic (Equus caballus)	20-30	62
48	Hyena, spotted (Crocuta crocuta)	12	♀25
49	Ibex, Nubian (Capra nubiana)	8.5	>10
50	Jackal, black-backed (Canis mesomelas)	8	13
51	Jaguar (Panthera onca)	14	>22
52	Kangaroo, red (Macropus rufus)		16.3
53	Lemur, black (Lemur macaco)	10	♂21
54	Leopard (Panthera pardus)	14	23
55	Lion (P. leo)	20-25	29
56	Llama (Lama glama)	15	20
57	Loris, slow (Nycticebus coucang)		10
58	Lynx, Canadian (Lynx canadensis)	6	>11
59	Marmoset (Hapale jacchus)	11	16
60	Marmot, alpine (Marmota marmota)	7	>13
61	Marten, pine (Martes martes)	10	>13.5
62	Mongoose, zebra (Mungos mungo)	5	♀>8
63	Monkey, bonnet (Macaca radiata)	♂12	13
64	Monkey, rhesus (M. mulatta)	15	29
65	Mouse, harvest (Micromys minutus)	2	2.5
66	Mouse, house (Mus musculus)	1-2	>3
67	Opossum (Didelphis spp)		>7
68	Orangutan (Pongo pygmaceus)	8	♂26
69	Otter (Lutra spp)		>15
70	Ox (Bos taurus)	20-25	30
71	Peccary, collared (Pecari tajucu)		>15
72	Platypus (Ornithorhynchus paradoxus)	5	
73	Porcupine, African (Hystrix cristata)	8-12	>20
74	Prairie dog (Cynomys ludovicianus)	4	>8
75	Puma (Felis concolor)	9	16
76	Rabbit, European (Oryctolagus cuniculus)	5-6	>13
77	Raccoon (Procyon lotor)	4	>13
78	Rat, house (Rattus rattus)	2-3	4
79	Reindeer (Rangifer tarandus)		15
80	Rhinoceros, Indian great (Rhinoceros unicornis)	40-45	47
81	Sea lion, California (Zalophus californianus)	13	19
82	Seal, cape fur (Arctocephalus pusillus)	13	♀>20

	Species	Recorded Life Span	
		Av yr	Max yr
	Vertebrata (continued)		
	Mammalia (concluded)		
83	Seal, common (Phoca vitulina)		>14
84	Sheep, domestic (Ovis aries)	10-15	20
85	Shrew, jumping (Elephantulus rozeti)		3.4
86	Skunk, Canadian (Mephitis mephitis)		6
87	Sloth, two-toed (Choloepus didactylus)		>11
88	Squirrel, gray (Sciurus carolinensis)	9	14-15
89	Swine (Sus scrofa)	16	27
90	Tapir, Brazilian (Tapirus terrestris)	<6	9
91	Tiger (Panthera tigris)	11	19
92	Weasel (Mustela nivalis)		>7
93	Whale, arctic (Balaena mysticetus)	24-37[1]	
94	Wolf, European (Canis lupus)	12	14
95	Woodchuck (Marmota monax)		>9
96	Yak (Peophagus grunniensis)		22
97	Zebra, mountain (Equus zebra)	22	>25
		Maximum yr	
	Aves		
98	Bird of paradise (Paradisea apoda)	>12	
99	Blackbird, European (Turdus merula)	18	
100	Bluebird (Sialis sialis)	4.5	
101	Bunting, red-headed (Emberiza luteola)	>13	
102	Buzzard, African (Buteo desertorum)	>18	
103	Canary, house (Serinus canarius)	24	
104	Cardinal (Richmondena cardinalis)	22	
105	Chickadee (Parus atricapillus)	>7	
106	Cockatoo, slender-billed (Kakatoe tenuirostris)	85[1]	
107	Condor (Vultur gryphus)	52	
108	Coot, slaty (Fulica ardesiaca)	3	
109	Cormorant (Phalacrocorax carbo)	23	
110	Cowbird, bay-winged (Molothrus badius)	>12	
111	Crane, common (Grus communis)	>42	
112	Dove, collared (Turtur risorius)	30-40	
113	Duck, domestic (Anas platyrhynchus domesticus)	19[2]	
114	Eagle, Chilean (Geranoaetus melanoleucus)	>42	
115	Egret, American snowy (Leucophoyx thula)	>16	
116	Emu (Dromiceius novaehollandiae)	40[1]	
117	Finch, chestnut-eared (Amadina castanotis)	>8	
118	Flamingo, European (Phoenicopterus roseus)	>22	
119	Fowl, domestic (Gallus domesticus)	30	
120	Goldfinch, European (Carduelis carduelis)	27	
121	Goose, Canadian (Branta canadensis)	32	
122	Gull, herring (Larus argentatus)	44	
123	Heron (Ardea cinerea)	>24	
124	Hornbill, Indian great (Buceros bicornis)	33	
125	Jay, blue (Cyanocitta cristata)	>4	
126	Kingfisher, laughing (Halcyon sp)	11	
127	Kiwi (Apteryx australis)	20[2]	
128	Lovebird, gray-headed (Agapornis cana)	>8	
129	Lyrebird (Menura superba)	>8	
130	Macaw, blue-and-yellow (Ara arrauana)	43	
131	Macaw, red-and-blue (A. macao)	64	
132	Magpie (Pica pica)	12	
133	Mockingbird (Mimus polyglottos)	>6	
134	Nightingale (Luscinia luscinia)	3.8	
135	Nuthatch, white-breasted (Sitta carolinensis)	>8	
136	Ostrich, African (Struthio camelus)	50	
137	Owl, barn (Tyto alba)	>13	
138	Owl, snowy (Nyctea nyctea)	24.5	
139	Parrot, Maximilian's (Pionus maximiliani)	9	
140	Parrakeet, ring-necked (Psittacula torquatus)	>20	
141	Partridge, European (Perdix perdix)	>5	
142	Pelican, Australian (Pelecanus conspicillatus)	52	
143	Penguin, king (Aptenodytes patagonica)	26	
144	Pheasant, ring-necked (Phasianus colchicus)	>27	
145	Pigeon, domestic (Columba livia domestica)	35	
146	Plover, old-world golden (Pluvialis apricaria)	>1	
147	Puffin, Atlantic (Fratercula arctica)	8[2]	
148	Quail, European (Coturnix coturnix)	10	
149	Raven (Corvus corax)	69	
150	Robin, American (Turdus migratorius)	>12	
151	Rook (Corvus frugilegus)	>14	
152	Skylark (Alauda arvensis)	24	
153	Sparrow, Italian (Passer italiae)	20	
154	Starling (Sturnus vulgaris)	>15	
155	Stork, black (Ciconia nigra)	30	
156	Swallow (Hirundo rustica)	<1	
157	Swan, trumpeter (Cygnus buccinator)	>29	
158	Thrush, song (Turdus musicus)	>11	
159	Titmouse, great (Parus major)	9	
160	Turkey (Meleagris gallopavo)	>12	
161	Vulture, griffon (Gyps fulvus)	41	
162	Waxbill, Amandava (Estrilda amandava)	>10	

[1] Reported as not authenticated. [2] Still alive at time of report.

Animals in wild state are indicated by an asterisk (*). When no symbol (♂,♀) precedes value, sex of animal is unspecified.

	Species	Recorded Life Span Maximum yr
	Vertebrata (continued)	
	Reptilia	
163	Alligator, American (Alligator mississipiensis)	56
164	Anaconda (Eunectes murinus)	28
165	Black snake (Coluber constrictor)	5.32
166	Boa constrictor (Constrictor constrictor)	>23
167	Caiman, black (Caiman niger)	28
168	Chameleon (Chameleon sp)	>3.5
169	Cobra, African black (Naja melanoleuca)	>26[2]
170	Cooter (Pseudemys scripta)	7
171	Copperhead, N. Am. (Anciatrodon contortrix)	18.5[2]
172	Cottonmouth, N. American (A. piscivorus)	21
173	Crocodile, American (Crocodylus acutus)	13.5
174	Carter snake (Thamnophis sirtalis)	6
175	Gecko, Moorish wall (Tarentola mauritanica)	7.4
176	Gila monster (Heloderma suspectum)	20
177	Iguana, Galapagos (Conolophus subcristatus)	15.1
178	King snake (Lampropeltis getulus californiae)	14.8
179	Lizard, European glass (Ophisaurus apus)	24
180	Lizard, long-tailed (Latastia longicaudata)	2.3
181	Lizard, monitor (Varanus salvator)	10.8[1]
182	Matamata (Chelys fimbriata)	10.3
183	Puff adder (Bitis arietans)	13.9
184	Python, African rock (Python sebae)	15.5
185	Rattlesnake, N. American (Crotalus atrox)	18.6
186	Skink, sand (Chalcides ocellatus)	>9.5
187	Terrapin, Reeve's (Geoclemys reevesii)	24.3
188	Tortoise, European pond (Emys orbicularis)	66
189	Tortoise, Galapagos (Testudo elephantopus)[3]	177
190	Tuatara (Sphenodon punctatus)	>28
191	Turtle, common box (Terrapene carolina)	123
192	Turtle, green (Chelonia mydas)	21.0[2]
193	Turtle, musk (Sternotherus odoratus)	53.12
194	Turtle, snapping (Chelydra serpentina)	202
195	Water mocassin (Ancistrodon piscivorus)	21
196	Water snake (Natrix sipedon)	7
197	Whip snake (Masticophis flagellum)	13.4
198	Viper, cape (Causus rhombeatus)	>6.5
	Amphibia	
199	Coecilian, S. American (Siphonops annulatus)	9.5
200	Congo "eel" (Amphiuma means)	26.8
201	Frog, African speckled (Rana adspersa)	5.4[1]
202	Frog, bull (R. catesbeiana)	>15.6
203	Frog, clawed (Xenopus laevis)	15
204	Frog, green (Rana clamitana)	>10.1
205	Frog, leopard (R. pipiens)	>5.9
206	Frog, palaearctic grass (R. temporaria)	>4.3
207	Frog, palaearctic water (R. esculenta)	>5.1
208	Frog, red-spotted (Leptodactylus pentadactylus),	15.7
209	Frog, S. African (Phrynomerus bifasciata)	>9.4
210	Hellbender (Cryptobranchus alleganiensis)	>28.5
211	Mudpuppy, N. American (Necturus maculosus)	>8.8
212	Newt, California (Taricha torosua)	21
213	Newt, common (Triturus viridescens)	2.9
214	Newt, European crested (T. cristatus)	17
215	Newt, Pyrenean (Euproctus asper)	>7
216	Proteus, European (Proteus anguinus)	15
217	Salamander, Asiatic (Megalobratrachus maximus)	55
218	Salamander, European (Salamandra atra)	3
219	Salamander, long-tailed (Eurycea lucifuga)	>1
220	Salamander, spotted (Ambystoma maculatum)	25
221	Salamander, tiger (A. tigrinum)	11
222	Siren, N. American (Siren lacertina)	25.5
223	Toad, American (Bufo americanus)	12-23
224	Toad, Cuban (B. pelitecephalus)	13
225	Toad, Degen's (B. vittatus)	2.4
226	Toad, giant (B. alvarius)	2
227	Toad, northwestern (B. boreas)	6
228	Toad, Surinam (Pipa pipa)	>7.8[2]
229	Tree-frog, Florida (Hyla gratiosa)	5.9
230	Tree-frog, giant (H. septentrionalis)	6.75
231	Tree-frog, palaearctic (H. arborea)	14
232	Tree-frog, rain (H. versicolor)	8.7
233	Tree-frog, S. American (H. raddiana)	2.3

	Species	Recorded Life Span Ay yr	Max yr
	Vertebrata (concluded)		
	Pisces (concluded)		
242	Cod, Atlantic (Gadus morhua)*		13
243	Dogfish (Scyliidae sp)		>2
244	Eel, electric (Electrophorus electricus)		11.5
245	Eel, N. American (Anguilla rostrata)		6
246	Flounder (Pleuronectes flesus)		10
247	Flounder, starry (Platichthys stellatus)		>8
248	Flounder, winter (Pleuronectes americanus)		1
249	Gar, longnose (Lepisosteus osseus)*		30
250	Goldfish (Cyprinus carassius auratus)		25
251	Grayling, American (Thymallus signifer)*	4	11
252	Grunion (Leuresthes tenuis)		4
253	Haddock (Melanogrammus aeglefinus)*	1.9	15
254	Halibut, Atlantic (Hippoglossus hippoglossus)		40
255	Herring, Pacific (Clupea pallasi)*	5.9	19
256	Lamprey, American brook (Lampetra lamottei)		5
257	Lungfish, African (Protopterus annectens)		>17
258	Lungfish, S. American (Lepidosiren paradoxa)		8.3
259	Mackerel, jack (Trachurus symmetricus)		>20
260	Mackerel, Pacific (Pneumatophorus diego)		11
261	Minnow, European (Phoxinus phoxinus)		13
262	Paddlefish (Polyodon spathula)		14
263	Perch (Perca fluviatilis)		>10.8
264	Perch, yellow (P. flavescens)*	3.4	13
265	Pickerel, chain (Esox niger)*	3.3	8
266	Pike (E. lucius)	4.6	24
267	Roach (Rutilus rutilus)		12
268	Salmon, Atlantic (Salmo salar)*		13
269	Salmon, pink (Oncorhynchus gorbuscha)*		1.8
270	Sardine, California (Sardinops caerulea)*	3.3	13
271	Seahorse (Hippocampus guttulatus)		6
272	Shark (Scyliorhinus stellaris)*		18
273	Shiner, common (Notropis cornutus)*		6
274	Smelt, American (Osmerus mordax)*	2.3	5
275	Smelt, jack (Atherinopsis californiensis)		9-10
276	Sole, Dover (Microstomus pacificus)		15
277	Squawfish, Sacramento (Ptychocheilus grandis)		9
278	Sturgeon, white (Acipenser transmontanus)		50
279	Sunfish, green (Lepomis cyanellus)*	2.2	9
280	Tautog (Tautoga onitis)		8
281	Trout, brown (Salmo trutta)*	3.2	18
282	Trout, lake (Salvelinus namaycush)*	7.6	41
283	Trout, rainbow (Salmo irideus)		>3.9
284	Tuna, bluefin (Thunnus thynnus)*		7
285	Walleye, yellow (Stizostedion vitreum)*	4.8	18
286	Whitefish, lake (Coregonus clupeaformis)*	5.3	26

	Invertebrata	Maximum yr
	Echinodermata	
	Asteroidea	
287	Starfish (Asterias rubens)	>5
	Holothuroidea	
288	Sea cucumber (Cucumaria planci)	>10
	Mollusca	
	Pelecypoda	
289	Clam, giant (Tridacna gigas)	60-100[1]
290	Mussel, edible (Mytilus edulis)	<1
291	Mussel, fresh-water (Margaritana margaritifera)	100[1]
292	Mussel, fresh-water (Pisidium spp)	2-4
293	Mussel, fresh-water (Unio crassus)	12
294	Mussel, pearl (Pinctada spp)	8
295	Mussel, pond (Anodonta fluviatilis)	10
296	Oyster (Ostrea edulis)	10
297	Scallop (Pecten jessoensis)	7
298	Shell, fingernail (Musculium spp)	2-4
299	Shell, fingernail (Sphaerium spp)	2-4
300	Shipworm (Teredo spp)	<1
	Gastropoda	
301	Opisthobranch (Gascoptercon meckelii)	1
302	Periwinkle (Littorina littorea)	20
303	Prosobranch, freshwater (Neritina spp)	5
304	Sea hare (Aplysia spp)	1
305	Shell, moon (Lunatia heros)	30
306	Slug (Milax marginatus)	2-3
307	Slug (Limax spp)	1-3
308	Slug, marine (Doris spp)	1
309	Slug, marine nudibranch (Aeolidia spp)	1
310	Slug, marine nudibranch (Janolus inatatus)	1
311	Snail, edible (Helix pomatia)	18[2]
312	Snail, fresh-water (Ancylus spp)	4-5
313	Snail, fresh-water (Lymnaea spp)	4-5
314	Snail, fresh-water (Planorbis spp)	4-5
315	Snail, land (Campylaea cingulata)	4-5

	Species	Recorded Life Span Maximum yr
	Pisces	
234	Anchovy, northern (Engraulis mordax)	7
235	Bass, large-mouth (Micropterus salmoides)	11[2]
236	Bass, small-mouth (M. dolomieu)	11[2]
237	Bass, striped (Roccus saxatilis)*	24
238	Bullhead, black (Ameiurus melas)*	9
239	Carp, mirror (Cyprinus carplo var.)	47[2]
240	Carp, Prussian (C. carpio)	<6.5
241	Catfish, flathead (Pilodictis olivaris)*	15

/1/ Reported as not authenticated. /2/ Still alive at time of report. /3/ May be Testudo radiata from Madagascar.

	Species	Maximum yr
	Invertebrata (continued)	
	Gastropoda (concluded)	
316	Snail, land (Helicigona, Arianta arbustorum)	4-5
317	Snail, pond (Viviparus contectus)	5
318	Snail, pulmonate (Paludina spp)	8-10
	Decapoda	
319	Squid (Loligo pealei)	>2
320	Squid (L. vulgaris)	>2
321	Squid, giant (Architeuthis spp)	10
	Amphineura	
322	Chiton, coat-of-mail shell (Chaetopleura apiculata)	4
	Arthropoda	
	Insecta	
323	Ant (Lasius spp)	10-15
324	Ant (Formica fusca)[4]	13
325	Ant, red (F. sanguinea)[5]	5
326	Aphid (Aphis evonymi)	0.08
327	Bedbug (Cimex lectularius)[6]	0.5
328	Bee, honey (Apis mellifera)[7]	0.6
329	Bee, honey (A. mellifera)[8]	5
330	Bee, honey (A. mellifera)[5]	0.8
331	Beetle (Cybister roeselii)	0.02
332	Beetle, buprestid (Eurythrea spp)	27†
333	Beetle, capricorn (Hylotrupes bajulus)	98
334	Beetle, chrysomelid (Timarsha spp)	5
335	Beetle, darkling (Akis lusitanica)	7
336	Beetle, darkling (Blaps spp)	6
337	Beetle, flour (Tribolium sp)	3
338	Beetle, ground (Carabidae)[8, 9]	7-11
339	Beetle, June (Melolontha vulgaris)[10]	4-5
340	Beetle, long-horned (Cerambycidae)[9]	45
341	Beetle, stag (Lucanus cervus)	6
342	Beetle, stag (L. cervus)[10]	0.02
343	Beetle, wood-boring (Buprestis splendens)	30
344	Booklouse (Liposcelis sp)	1.04
345	Cerambycid (Cerambyx sp)[10]	45
346	Cerambycid (Hesperophanes mixtus)[10]	9-10
347	Cerambycid (Stromatium fulvum)	11
348	Chafer, rose (Cetonia aurata)	6
349	Cicada, periodical (Magicicada septendecim)	17
350	Cricket (Gryllotalpa spp)	1
351	Earwig (Forficula auricularia)	5
352	Fly, fruit (Drosophila melanogaster)[11]	0.1
353	Fly, fruit (D. melanogaster)[12]	0.05
354	Fly, house (Musca domestica)	0.2
355	Fly, syrphid (Eristalis tenax)	0.09
356	Grasshopper (Melanoplus differentialis)	0.2
357	Grasshopper, short-horned (Acrididae)[9]	<1
358	Maggot, apple (Rhagoletis pomonella)	0.3
359	Mantis, praying (Mantis religiosa)	8
360	Mosquito (Aedes geniculatus)	1.5
361	Roach, American (Periplaneta americana)	4.6
362	Roach, German (Blatella germanica)	1.3
363	Silverfish (Lepisma saccharina)	2
	Chilopoda	
364	Centipede, garden (Scutigerella immaculata)	0.9-1
365	Stone-crawler (Lithobius forificatus)	3
	Arachnida	
366	Spider, bird- (Avicularis aviculariis)	15
367	Spider, house (Tegenaria civilis)	0.01
368	Spider, purse-web (Atypus piceus)	7‡3
369	Spider, British trapdoor (A. sp)	0.02
370	Spider, American tarantula (Mygali hentzii)	0.02
371	Tick, Rocky Mt. wood (Dermacentor andersoni)	3-4
	Crustacea	
372	Crab, fresh-water (Astacus fluviatilis)	30
373	Crustacea, fresh-water (spp)	1-1.5
374	Flea, water (Daphnia sp)[14]	7
375	Flea, water (D. magna)	0.2
376	Flea, water cladocera (D. longispina)	0.1
377	Lobster, European (Homarus gammarus)	33
378	Ostracod (Cyprinotus incongruens)	0.2-0.3
379	Ostracod (Herpetocypris strigata)	1.1
	Annelida	
	Polychaeta	
380	Sandworm (Platynereis dumerilii)	<1
	Oligochaeta	
381	Earthworm (Lumbricus terrestris)	10
	Hirudinea	
382	Leech (Hirudo medicinalis)	27
	Nemathelminthes	
	Nematoda	
383	Eyeworm (Loa loa)	15
384	Filaria (Wuchereria bancrofti)	17
385	Hookworm (Ancylostoma duodenale)	7
386	Hookworm (A. caninum)[15]	2

	Species	Maximum yr
	Invertebrata (concluded)	
	Nematoda (concluded)	
387	Hookworm (Necator americanus)	12
388	Immitis (Dirofilaria spp)[15]	7
389	Kidneyworm, giant, dog (Dioctophyme renale)	2
390	Lungworm, dog (Oslerus osleri)	0.4
391	Oxyurid, mice (Heterakis spumosa)	0.8
392	Nematode (Enterobius vermicularis)	0.1
393	Nematode (Haemonchus contortus)	1
394	Nematode (Trichostrongylus sp)	8.5
395	Nematode (Anguina tritici)[16]	27
396	Nematode (Ditylenchus dipsaci)[16]	9
397	Nematode (Pratylenchus pratensis)[17]	11
398	Nematode (Tylenchus polyhypnus)	39
399	Nemstode, free-living (Cephalobus dubius)	0.4
400	Nematode, free-living (Diplogaster robustus)	0.04
401	Nematode, free-living (Pristionchus acrivora)	0.1
402	Nematode, free-living (Rhabditis elegans)	0.03
403	Nematode, trichinella (Trichinella spiralis)[18]	0.4
404	Nematode, trichinella cysts (T. spiralis)	30
	Acanthocephala	
405	Acanthocephalan, pig (Macracanthorhynchus hirudinaceus)	1
	Gastrotricha	
406	Gastrotrich (Lepidodermella squamatum)	0.05
	Rotifera	
407	(Adinota barbata)	0.06
408	(A. vaga)	0.06
409	(Asplanchna sieboldii)	0.05
410	(Brachionus pala)	0.05
411	(Cupelopagis vorax)	0.1
412	(Ephines brachionus)	0.04
413	(E. senta)	0.02
414	(Euchlanis dilatata)	0.06
415	(E. triquetra)	0.06
416	(Floscularia conifera)	0.05
417	(Habrotrocha constricta)	0.09
418	(Keratella sculeata)	0.08
419	(Lecane inermis)	0.03
420	(Macrotrachela quadricornifera)	0.1
421	(Mniobia russeola)	0.08
422	(Philodina citrina)	0.06
423	(P. magalotrocha)	0.04
424	(P. roseola)	0.02
425	(Prales sordida)	0.02
426	(Proales decipiena)	0.03
427	(Rotaria macrura)	0.1
428	(R. rotatoria)	0.1
	Platyhelminthes	
	Turbellaria	
429	Flatworm (Planaria torva)	1.1
430	Worm, polyclad (Yungia aurantiaca)	1
	Cestoda	
431	Tapeworm, beef (Taenia saginata)[19]	0.09
432	Tapeworm, fish (Diphyllobothrium latum)[19]	0.09
433	Tapeworm, sheep (Monieia expansa)	0.1
	Coelenterata	
	Hydrozoa	
434	Hydra, fresh-water (Hydra grisea)	1-2
	Scyphozoa	
435	Jelly-fish (Cotylorhiza tuberculata)	0.5-0.6
	Anthozoa	
436	Coral (Favites spp)	>22-28
437	Coral (Goniastrea spp)	>22-28
438	Coral (Montastrea spp)	>22-28
439	Coral (Poollopora spp)	>22-28
440	Coral, solitary (Flabellum sp)	24
441	Sea-anemone (Actinia equina)	67
442	Sea-anemone (Cerianthus membranaceus)	40
443	Sea-anemone (Heliactis bellis)	20
444	Sea-anemone (Sagartia troglodytes)	50
	Porifera	
	Demospongiae	
445	Sponge, commercial (Hippospongia sp)	50
446	Sponge, siliceous (Axinella sp)	4
	Calcispongiae	
447	Sponge, calcareous (Scypha capillasa)	0.2
	Protozoa	
	Sarcodina	
448	(Elphidium crispum)	2-4
	Flagellata	
449	(Mastigamoeba sp)[20]	20
450	(Oikomonas sp)[20]	20
	Ciliata	
451	(Didnium nastum)[20]	10

[1] Reported as not authenticated. [4] Queen. [5] Worker. [6] Unfed female. [7] Drone. [8] Including developmental period. [9] Family name. [10] Larva. [11] Normal strain. [12] Vestigial strain. [13] Three years as adult. [14] Winter eggs. [15] In dog. [16] Desiccated in dry wheat gall. [17] Desiccated in fig roots. [18] Adults in guinea pigs. [19] In man. [20] Cysts.

153. LIFE SPAN: TREES AND SHRUBS

Life span refers to age at natural death. There is great variation from the approximate ages given in table, and some individuals of each species live much longer than indicated.

	Species	Life Span yr
	Forest Trees, U.S.A.	
1	Alaska-cedar (Chamaecyparis nootkatensis)	300-600
2	Alder, red (Alnus rubra)	60-100
3	Ash, blue (Fraxinus quadrangulata)	200-300
4	Ash, Oregon (F. latifolia)	150-250
5	Ash, white (F. americana)	260-300
6	Aspen, bigtooth (Populus grandidentata)	70-100
7	Aspen, quaking (P. tremuloides)	70-100
8	Baldcypress (Taxodium distichum)	600-1200
9	Basswood, American (Tilia americana)	100-140
10	Beech, American (Fagus grandifolia)	300-400
11	Birch, gray (Betula populifolia)	50
12	Birch, paper (B. papyrifera)	80-100
13	Birch, sweet (B. lenta)	150-250
14	Birch, yellow (B. alleghaniensis)	150-300
15	Buckeye, yellow (Aesculus octandra)	60-80
16	Buckthorn, cascara (Rhamnus purshiana)	40-50
17	Butternut (Juglans cinerea)	80
18	California-laurel (Umbellularia californica)	200
19	Catalpa, northern (Catalpa speciosa)	100
20	Cherry, black (Prunus serotina)	100-200
21	Chestnut, American (Castanea dentata)	100-300
22	Chinkapin, golden (Castanopsis chrysophylla)	200-400
23	Cottonwood, black (Populus trichocarpa)	150-200
24	Cottonwood, eastern (P. deltoides)	60-100
25	Cottonwood, plains (P. sargentii)	50-90
26	Cucumbertree (Magnolia acuminata)	80-250
27	Cypress, Arizona (Cupressus arizonica)	100-300
28	Dogwood, Pacific (Cornus nuttallii)	125
29	Douglas-fir (Pseudotsuga menziesii)	300-700
30	Elm, American (Ulmus americana)	150-300
31	Elm, rock (U. thomasii)	250
32	Elm, slippery (U. rubra)	300
33	Fir, alpine (Abies lasiocarpa)	150-200
34	Fir, balsam (A. balsamea)	100-150
35	Fir, California red (A. magnifica)	250-400
36	Fir, grand (A. grandis)	200-400
37	Fir, noble (A. procera)	300-500
38	Fir, Pacific silver (A. amabilis)	250-300
39	Fir, white (A. concolor)	150-400
40	Hackberry (Celtis occidentalis)	75-150
41	Hemlock, eastern (Tsuga canadensis)	300-600
42	Hemlock, mountain (T. mertensiana)	200-500
43	Hemlock, western (T. heterophylla)	300-600
44	Hickory, bitternut (Carya cordiformis)	175
45	Hickory, mockernut (C. tomentosa)	200-300
46	Hickory, pignut (C. glabra)	200-300
47	Hickory, shagbark (C. ovata)	250-300
48	Hickory, shellbark (C. laciniosa)	350
49	Hickory, water (C. aquatica)	125
50	Holly, American (Ilex opaca)	100-150
51	Honeylocust (Gleditsia triacanthos)	120
52	Incense-cedar (Libocedrus decurrens)	300-400
53	Juniper, alligator (Juniperus deppeana)	300-500
54	Juniper, Rocky Mt. (J. scopulorum)	100-300
55	Juniper, Utah (J. osteosperma)	150-300
56	Juniper, western (J. occidentalis)	300
57	Larch, western (Larix occidentalis)	300-600
58	Locust, black (Robinia pseudoacacia)	60-100
59	Magnolia, southern (Magnolia grandiflora)	80-120
60	Maple, bigleaf (Acer macrophyllum)	150-300
61	Maple, red (A. rubrum)	80-250
62	Maple, silver (A. saccharinum)	50-125
63	Maple, sugar (A. saccharum)	200-300
64	Mulberry, red (Morus rubra)	125
65	Oak, black (Quercus velutina)	150-200
66	Oak, blackjack (Q. marilandica)	100
67	Oak, bur (Q. macrocarpa)	200-400
68	Oak, Calif. black (Q. kelloggii)	175-300
69	Oak, Calif. live (Q. agrifolia)	150
70	Oak, Calif. white (Q. lobata)	200-300
71	Oak, canyon live (Q. chrysolepis)	200-300
72	Oak, chestnut (Q. prinus)	300-400
73	Oak, live (Q. virginiana)	200-300
74	Oak, northern red (Q. rubra)	200-400
75	Oak, overcup (Q. lyrata)	300-400
76	Oak, pin (Q. palustris)	125-150
77	Oak, post (Q. stellata)	250
78	Oak, scarlet (Q. coccinea)	150
79	Oak, southern red (Q. falcata)	200-275
80	Oak, swamp chestnut (Q. michauxii)	100-200
81	Oak, swamp white (Q. bicolor)	300
82	Oak, water (Q. nigra)	175
83	Oak, white (Q. alba)	300-600
84	Osage-orange (Maclura pomifera)	75-100
85	Pecan (Carya illinoensis)	300

	Species	Life Span yr
	Forest Trees, U.S.A. (concluded)	
86	Persimmon (Diospyros virginiana)	60-80
87	Pine, digger (Pinus sabiniana)	80-150
88	Pine, eastern white (P. strobus)	300-500
89	Pine, jack (P. banksiana)	80-150
90	Pine, jeffrey (P. jeffreyi)	300-500
91	Pine, knobcone (P. attenuata)	100-150
92	Pine, limber (P. flexilis)	200-400
93	Pine, loblolly (P. taeda)	150-250
94	Pine, lodgepole (P. contorta)	120-300
95	Pine, longleaf (P. palustris)	300-400
96	Pine, pitch (P. rigida)	100-200
97	Pine, ponderosa (P. ponderosa)	300-500
98	Pine, red (P. resinosa)	200-350
99	Pine, shortleaf (P. echinata)	200-300
100	Pine, slash (P. elliottii)	150-250
101	Pine, spruce (P. glabra)	75-150
102	Pine, sugar (P. lambertiana)	300-600
103	Pine, Virginia (P. virginiana)	100-200
104	Pine, western white (P. monticola)	200-500
105	Pinyon (P. edulis)	150-400
106	Pinyon, singleleaf (P. monophylla)	150-225
107	Poplar, balsam (Populus balsamifera)	100-150
108	Port-Orford-cedar (Chamaecyparis lawsoniana)	300-500
109	Redcedar, eastern (Juniperus virginiana)	150-300
110	Redcedar, western (Thuja plicata)	500-800
111	Redwood (Sequoia sempervirens)	800-1500
112	Sassafras (Sassafras albidum)	100-500
113	Sequoia, giant (Sequoia gigantea)	2000-3000
114	Spruce, black (Picea mariana)	150-250
115	Spruce, blue (P. pungens)	150-350
116	Spruce, Engelmann (P. engelmannii)	200-500
117	Spruce, red (P. rubens)	200-300
118	Spruce, Sitka (P. sitchensis)	400-750
119	Spruce, white (P. glauca)	150-350
120	Sweetgum (Liquidambar styraciflua)	250-300
121	Sycamore, American (Platanus occidentalis)	250-500
122	Tamarack (Larix laricina)	100-200
123	Tanoak (Lithocarpus densiflora)	150-300
124	Walnut, black (Juglans nigra)	150-250
125	White-cedar, Atlantic (Chamaecyparis thyoides)	100-200
126	White-cedar, northern (Thuja occidentalis)	300-400
127	Willow, black (Salix nigra)	50-125
128	Willow, peachleaf (S. amygdaloides)	50-100
129	Yellow-poplar (Liriodendron tulipifera)	250-450
130	Yew, Pacific (Taxus brevifolia)	250-350
	Various Trees and Shrubs	
131	Alder, European (Alnus glutinosa)	100
132	Barberry, European (Berberis vulgaris)	25
133	Beech, European (Fagus sylvatica)	600
134	Birch, European (Betula pubescens)	125
135	Buckthorn, European (Rhamnus cathartica)	100
136	Catalpa, southern (Catalpa bignonioides)	60
137	Cedar-of-Lebanon (Cedrus libanensis)	1200
138	Cotoneaster, European (Cotoneaster integerrima)	15
139	Cypress, Italian (Cupressus sempervirens)	2000
140	Dogwood, bloodtwig (Cornus sanguinea)	50
141	Dogwood, Cornelian (C. mas)	300
142	Elder, European (Sambucus nigra)	100
143	Elder, European red (S. racemosa)	20
144	Fig, religious (Ficus religiosa)	2000
145	Filbert, European (Corylus avellana)	150
146	Filbert, Turkish (C. colurna)	100
147	Hawthorn, English (Crataegus oxyacantha)	400
148	Honeysuckle, woodbine (Lonicera periclymenum)	40
149	Hophornbeam, European (Ostrya carpinifolia)	100
150	Hornbeam, American (Carpinus caroliniana)	100
151	Hornbeam, European (C. betulus)	250
152	Juniper, common (Juniperus communis)	2000
153	Maple, Norway (Acer platanoides)	400
154	Mountain-ash, European (Sorbus aucuparia)	80
155	Pine, Austrian (Pinus nigra)	600
156	Pine, Scotch (P. sylvestris)	500
157	Pine, Swiss stone (P. cembra)	1200
158	Poplar, white (Populus alba)	300
159	Rhododendron, garland (Rhododendron hirsutum)	50
160	Rhododendron, rock (R. ferrugineum)	40
161	Service-tree (Sorbus domestica)	140
162	Service-tree (S. torminalis)	230
163	Spruce, Norway (Picea abies)	400
164	Walnut, English (Juglans regia)	300
165	Willow, myrtle (Salix myrsinites)	100
166	Willow, white (S. alba)	150
167	Wisteria, Chinese (Wisteria sinensis)	60
168	Yew, English (Taxus baccata)	900

154. LIFE SPAN: POLLEN

	Species	Storage Conditions		Life Span[1]	Germination[2]
		Temp. °C	Rel. Hum. %	da	%
	Field and Forage Crops				
1	Barley (Hordeum vulgare)	2.2[3]		19	41
2	Bluegrass (Poa compressa)	17.5-21[4]		1	
3	Clover (Trifolium hybridum)	24[5]	Air dry	12	
4	Corn (Zea mays)	5-10	50-70	3	70[6]
5	Cotton (Gossypium pima var.)	4.4-10		4[3]	64[6]
6	Foxtail-grass (Alopecurus pratensis)	17.5-21[4]		2	
7	Hemp (Cannabis sativa)	17.5-21[4]	07	8	
8	Orchardgrass (Dactylis glomerata)	17.5-21[4]	30	3	
9	Rye (Secale cereale)	17.5-21[4]		0.5	
10	Ryegrass (Lolium perenne)	17.5-21[4]		1	
11	Sweetclover (Melilotus alba)	17.5-21[4]	30	96	
	Fruit and Nut Crops				
12	Almond (Prunus amygdalus)	7-18		1130	24
13	Apple (Pyrus malus)	2-8	50	1460	20
14	Apricot (Prunus armeniaca)	2-8	50	935	25
15	Avocado (Persea americana)[8]	15	09	155	
16	Cherry, sour (Prunus cerasus)	2-8	50	1460	20
17	Cherry, sweet (P. avium)	7-18		745	26
18	Date (Phoenix dactylifera)	1,1[10]		275	876[11]
19	Filbert (Corylus avellana)	17.5-21[4]	07	65	
20	Grape (Vitis spp[8]	7-12	28	1460	6-21
21	Grapefruit (Citrus paradisi)	10[12]		42	50
22	Papaya (Carica papaya)	1.1	10	150	45
23	Peach (Prunus persica)	2-8	50	1100	1-20
24	Pear (Pyrus communis)	2-8	50	1280	20
25	Pecan (Carya illinoensis)	5		4	40
26	Pistachio (Pistacia atlantica)	2.2	25	550	30
27	Plum (Prunus domestica)	2-8	50	1280	20
28	Quince (Cydonia oblonga)	2.2	25	550	54
29	Strawberry (Fragaria spp)	2-8	Air dry	>16	
30	Walnut (Juglans sieboldiana)	0	40-60	255	12
	Ornamental Plants				
31	Azalea (Rhododendron molle)	17.5-21[4]	30	175	
32	Bellflower (Campanula persicifolia)	24[5]	Air dry	21	
33	Buttercup (Ranunculus acris)	17.5-21[4]	30	49	
34	Camellia (Camellia japonica)	24[5]	Air dry	60	
35	Cyclamen (Cyclamen persicum)	17-22	07	185	

	Species	Storage Conditions		Life Span[1]	Germination[2]
		Temp. °C	Rel. Hum. %	da	%
	Ornamental Plants (concluded)				
36	Day lily (Hemerocallis flava)	17.5-21[4]	07	29	
37	Deutzia (Deutzia scabra)	24[5]	Air dry	20	
38	Gladiolus (Gladiolus hybrida)	10	50	100	30[13]
39	Iris (Iris pseudocorus)	24[5]	Air dry	28	
40	Lily (Lilium spp)	10	35-50	425	>45
41	Mockorange (Philadelphus floribundus)	24[5]	Air dry	32	
42	Narcissus (Narcissus poeticus)	24[5]	Air dry	72	
43	Narcissus (N. pseudonarcissus)	24[5]	Air dry	80	
44	Nasturtium (Tropaeolum majus)	17.5-21[4]	07	88	
45	Nicotiana (Nicotiana sylvestris)			205[14]	
46	Poppy (Eschscholtzia californica)	17-22	09	19	
47	Poppy (Papaver rhoeas)	17.5-21[4]	07	97	
48	Primrose (Oenothera biennis)	17.5-21[4]	Air dry	8	
49	Primrose (Primula elatior)	17.5-21[4]	07	180	
50	Rhododendron (Rhododendron spp)	24[5]	Air dry	42	
51	Snapdragon (Antirrhinum majus)	10-22		670	50[15]
52	Stock (Matthiola spp)	5-10	07	64	20
53	Sweetpea (Lathyrus odoratus)	24[5]	Air dry	23[6]	
54	Tulip (Tulipa gesneriana)	17.5-21[4]	30	110	
55	Violet (Viola odorata)	17.5-21[4]	07	235	
56	Waterlily (Nymphaea alba)	17.5-21[4]	07	35	
	Trees				
57	Basswood (Tilia platyphyllos)	17.5-21[4]	07	16	
58	Beech (Fagus sylvatica)	24[5]	Air dry	41	
59	Birch (Betula verrucosa)	24[5]		16	20
60	Cinchona (Cinchona hybrida)	10	38	145	23[16]
61	Ginkgo (Ginkgo biloba)	9	0-95	3650	
62	Goldenchaintree (Laburnum anagyroides)	17.5-21[4]	30	260	
63	Locust (Robinia pseudoacacia)	24[5]	Air dry	30	
64	Maple (Acer sp)	17-22	Air dry	18	8
65	Oak (Quercus coccinea)	2	35-95	19	46
66	Pine, red (Pinus resinosa)[17]	0-4	50	415	92[18]
67	Pine, Scotch (P. sylvestris)	17.5-21[4]	07	280	
68	Rubber-tree (Hevea sp)	6	67-80	19	
69	Spruce (Picea glauca)	219	10-75	365	60
70	Tung oil tree (Aleurites fordii)	5[3]		24	>40
71	Willow (Salix spp)	-3 to 3		50	2-10

/1/ Demonstrated viability in storage. /2/ Values are number of pollen grains germinating, expressed as percentages of total pollen grains tested at age specified under life span, unless otherwise indicated. Where no value is given data are not available. /3/ Flower spike or flower cut in early morning and kept under refrigeration. /4/ Average temperature for tests conducted during winter was 17.5°C; during summer, 21°C. /5/ Storage at room temperature. /6/ Data recorded on basis of seed or fruit set. /7/ Storage over concentrated sulfuric acid in desiccator. /8/ Horticultural varieties. /9/ Storage over calcium chloride in desiccator. /10/ Pollen stored in sealed or stoppered vial. /11/ At end of 365 days, 69%. /12/ Pollen stored under reduced pressure in evacuated and sealed tubes. /13/ Data recorded on basis of seed set per capsule. /14/ Sealed in ampules in vacuum or CO_2. /15/ Germination weak; no fruit set after storage of 161 days of 0°C. /16/ At end of 371 days, 6%. /17/ Data also applicable to white pine (P. strobus). /18/ Humidified at 75% relative humidity and 4°C for 12 hours after storage. /19/ Stored in darkness.

155. TEMPERATURE EFFECT ON LIFE SPAN: SEEDS

Seeds stored in sealed containers.

	Species	Moisture Content[1] %	Median Life Span[2]	Maximum Life Span[3]	Median Life Span[2]	Maximum Life Span[3]	Median Life Span[2]	Maximum Life Span[3]
			yr at 24°C[4]		yr at 5°C		yr at -4°C	
1	Ash (Fraxinus excelsior)	7	1	<2	7	<8		
2	Ash (F. pennsylvanica)	7	2	5	8	<9		
3	Aster (Callistephus chinensis)	7	2	3	10	12	>15	>15
4	Carrot (Daucus carota)	5	16	>20			>20	>20
5	Cauliflower (Brassica oleracea botrytis)	Air dry	>3	8				
6	Cinchona (Cinchona ledgeriana)	6	2	4	7	8	>9	>9
7	Cotton (Gossypium spp)	5	1	8	>13	>13	>13	>13
8	Dandelion (Taraxacum officinale)	6	6	>11	>14	>14	>14	>14
9	Eggplant (Solanum melongena)	5	18	>20			>20	>20
10	Elm (Ulmus americana)	7	2	4	8	10	15	>15
11	Fir (Abies grandis)	11	<1	<1	1	>10		>16
12	Fir (A. procera)	11	<1	1	1	>10		>16
13	Gladiolus (Gladiolus spp)	8	6	10	7	8	>10	>10
14	Grapefruit (Citrus paradisi)	60	<1	1	1	>1	<1	<1
15	Larkspur (Delphinium spp) Annual	Air dry	5	9	16	19	>18	>18
16	Perennial	Air dry	2	3	7	13	>18	>18
17	Lemon (Citrus limonia)	56	<1	<1	>1	>1	<1	<1
18	Lettuce (Lactuca sativa)	4	13	15			>20	>20
19	Lily (Lilium regale)	5	8	11	13	14	>17	>17
20	Onion (Allium cepa)	6	11	14			>20	>20
21	Pansy (Viola spp)	4	2	>3	3	4	>2	>2
22	Peony (Paeonia suffruticosa)	Air dry	<1	<1	3	8	5	7
23	Pepper (Capsicum frutescens)	5	8	12			>20	>20
24	Pine (Pinus caribaea)	Air dry	4	8	8	>8	>10	>10
25	Pine (P. echinata)	Air dry	1	2	11	>11	>12	>12
26	Pine (P. palustris)	Air dry	<1	<1	1	5	4	>6
27	Pine (P. taeda)	Air dry	1	2	10	>11	>12	>12
28	Spruce (Picea abies)	5					17	>17
29	Sweetpea (Lathyrus spp)	10	2	4	>3	>3		
30	Tomato (Lycopersicon esculentum)	5	17	>20			>20	>20
31	Venidium (Venidium spp)	5	>4	>4	>4	>4	>4	>4
32	Verbena (Verbena hecrioides)	6	3	6	9	13	>15	>15

/1/ At time of storage. /2/ Years for 50% seed survival. /3/ Maximum life span for a single seed. /4/ Temperature of laboratory, approximately 24°C.

156. FOODS OF PLANT ORIGIN: COMPOSITION

Values are per 100 g of edible portion of fresh, uncooked food, unless otherwise specified. Values based on inadequate evidence are enclosed in parentheses.

	Food	Water	Food Energy	Protein	Fat	Carbohydrate		Ash	Ca	Fe	P	Vita-min A	Ascor-bic Acid	Niacin	Ribo-flavin	Thia-mine
						Total	Fiber									
		g	Cal	g	g	g	g	g	mg	mg	mg	I. U.	mg	mg	mg	mg
1	Apple (Pyrus malus)	84.1	58	0.3	0.4	14.9	1.0	0.3	6	0.3	10	90	5	0.2	0.03	0.04
2	Apricot (Prunus armeniaca)	85.4	51	1.0	0.1	12.9	0.6	0.6	16	0.5	23	2790	7	0.8	0.05	0.03
3	Asparagus (Asparagus officinalis)	93.0	22	2.2	0.2	3.9	0.7	0.7	21	0.9	62	1000	33	1.4	0.19	0.16
4	Avocado (Persea gratissima)	65.4	245	1.7	26.4	5.1	1.8	1.4	10	0.6	38	290	16	1.1	0.13	0.06
5	Banana (Musa paradisiaca sapientum)	74.8	88	1.2	0.2	23.0	0.6	0.8	28	8	0.6	430	10	0.7	0.05	0.04
6	Barley, pearled, dry (Hordeum vulgare)	11.1	349	8.2	1.0	78.8	0.5	0.9	189	16	(2.0)	0	0	3.1	0.08	0.12
7	Bean, common, dried (Phaseolus vulgaris)	12.2	336	23.1	1.7	59.4	3.5	3.6	163	6.9	437	(0)	2	2.5	0.22	0.57
8	Bean, lima, immature (P. lunatus mac.)	66.5	128	7.5	0.8	23.5	1.5	1.7	63	2.3	158	280	32	1.4	0.11	0.21
9	Bean, lima, mature (P. lunatus macrocarpus)	12.6	333	20.7	1.3	61.6	4.3	3.8	88	7.5	381	0	2	2.0	0.18	0.48
10	Bean, snap, green and yellow (P. vulgaris)	88.9	35	2.4	0.2	7.7	1.4	0.8	65	1.1	44	630[1]	19	0.5	0.11	0.08
11	Beet, garden (Beta vulgaris)	87.6	42	1.6	0.1	9.6	0.9	1.1	27	1.0	43	20	10	0.4	0.05	0.02
12	Blackberry (Rubus spp)	84.8	57	1.2	1.0	12.5	4.2	0.5	32	0.9	32	200	21	0.4	0.04	0.04
13	Blueberry (Vaccinium corymbosum)	83.4	61	0.6	0.6	15.1	1.2	0.3	16	0.8	13	280	16	(0.3)	(0.02)	(0.02)
14	Brazil nut (Bertholletia excelsa)	5.3	646	14.4	65.9	11.0	2.1	3.4	186	3.4	693	Trace				0.86
15	Broccoli (Brassica oleracea botrytis)	89.9	29	3.3	0.2	5.5	1.3	1.1	130	1.3	76	3500	118	1.1	0.2	0.10
16	Brussels sprouts (B. oleracea gemmifera)	84.9	47	4.4	0.5	8.9	1.3	1.3	34	1.3	78	400	94	0.7	0.16	0.08
17	Cabbage (B. oleracea capitata)	92.4	24	1.4	0.2	5.3	1.0	0.8	46	0.5	31	80	50	0.3	0.05	0.06
18	Cantaloupe (Cucumis melo cantalupensis)	94.0	20	0.6	0.2	4.6	0.6	0.6	17	0.4	16	3420	33	0.5	0.04	0.05
19	Carrot (Daucus carota)	88.2	42	1.2	0.3	9.3	1.1	1.0	39	0.8	37	12000	0.5	0.06	0.06
20	Cauliflower (Brassica oleracea botrytis)	91.7	25	2.4	0.3	4.9	0.9	0.8	22	1.1	72	90	69	0.6	0.10	0.11
21	Celery (Apium graveolens)	93.7	18	1.3	0.2	3.7	0.7	1.1	50	0.5	40	0	7	0.4	0.04	0.05
22	Cherry, sour and sweet (Prunus spp)	83.0	61	1.1	0.5	14.8	0.3	0.6	18	0.4	20	620	8	0.4	0.06	0.05
23	Coconut (Cocos nucifera)	46.9	359	3.4	34.7	14.0	3.2	1.0	21	2.0	98	0	2	0.2	0.02	0.10
24	Collard (Brassica acephala)	86.6	40	3.9	0.6	7.2	1.2	1.7	249	1.6	58	6870	100	(2.0)	0.27	0.11
25	Corn, sweet, white and yellow (Zea mays)	73.9	92	3.7	1.2	20.5	0.8	0.7	9	0.5	120	390	12	1.7	0.12	0.15
26	Cranberry (Vaccinium macrocarpon)	87.4	48	0.4	0.7	11.3	1.4	0.2	14	0.6	11	60	12	0.1	(0.02)	(0.03)
27	Cucumber (Cucumis sativus)	96.1	12	0.7	0.1	2.7	0.5	0.4	10	0.3	2[1]	0[2]	8	0.2	0.04	0.03
28	Currant, red (Ribes rubrum)	84.4	55	1.2	0.2	13.6	4.0	0.6	36	0.9	33	120	36			0.04
29	Date, dried (Phoenix dactylifera)	20.0	284	2.2	0.5	75.4	2.4	1.8	72	2.1	60	50	0	(0)	2.2	0.10	0.09
30	Eggplant (Solanum melongena)	92.7	24	1.1	0.2	5.5	0.9	0.5	15	0.4	37	30	5	0.6	0.05	0.04
31	Fig, dried (Ficus carica)	24.0	270	4.0	1.2	68.4	5.8	2.4	186	3.0	111	80	(0)	1.7	0.12	0.16
32	Grape, American (Vitis spp)[3]	81.9	70	1.4	1.4	14.9	0.5	0.4	17	0.6	21	80	4	0.2	0.04	0.06
33	Grapefruit (Citrus paradisi)	88.8	40	0.5	0.2	10.1	0.3	0.4	22	0.2	18	Trace	40	0.2	0.02	0.04
34	Guava (Psidium guajava)	80.6	70	1.0	0.6	17.1	5.5	0.7	30	0.7	29	250	302	1.2	0.04	0.07
35	Kale (Brassica oleracea acephala)	86.6	40	3.9	0.6	7.2	1.2	1.7	225	2.2	62	7540	115	2.0	0.23	0.10
36	Lemon (Citrus limonia)	89.3	32	0.9	0.6	8.7	0.9	0.5	40	0.6	22	0	50	0.1	Trace	0.04
37	Lettuce (Lactuca sativa)	94.8	15	1.2	0.2	2.9	0.6	0.9	22	0.5	25	540	8	0.2	0.08	0.04
38	Mango (Mangifera indica)	81.4	66	0.7	0.2	17.2	1.0	0.5	9	0.2	13	6350	41	0.9	0.06	0.06
39	Mushroom (Agaricus campestris)	91.1	16	2.4	0.3	4.0	0.9	1.1	9	1.0	115	0	5	4.9	0.44	0.10
40	Mustard greens (Brassica japonica)	92.2	22	2.3	0.3	4.0	0.8	1.2	220	2.9	38	6460	102	0.8	0.20	0.09
41	Okra, rolled (Avena sativa)	8.3	390	14.2	7.6	68.2	1.2	1.9	53	4.5	405	(0)	1.0	0.14	0.60
42	Okra (Hibiscus esculentus)	89.8	32	1.8	0.2	7.4	1.0	0.8	82	0.7	62	740	30	1.1	0.07	0.08
43	Onion, immature, green (Allium cepa)	87.6	35	1.0	0.2	10.6	1.8	0.6	135	0.9	24	(50)	24	(0.2)	(0.04)	(0.03)
44	Onion, mature (A. cepa)	87.5	45	1.4	0.3	10.3	0.8	0.6	32	0.5	44	50	9	0.2	0.04	0.03
45	Orange (Citrus spp)	87.2	45	0.9	0.2	11.2	0.6	0.5	33	0.4	23	(190)	49	0.2	0.03	0.08
46	Papaya (Carica papaya)	88.7	39	0.6	0.1	10.0	0.9	0.6	20	0.3	16	1750	56	0.3	0.04	0.03
47	Parsnip (Pastinaca sativa)	78.6	78	1.5	0.5	18.2	2.2	1.2	57	0.7	80	0	18	0.2	0.12	0.08
48	Pea, garden, immature (Pisum sativum)	74.3	98	6.7	0.4	17.7	2.2	0.9	22	1.9	122	680	26	2.7	0.16	0.34
49	Pea, garden, mature, dried (P. sativum)	11.6	339	23.8	1.4	60.2	5.4	3.0	57	4.7	388	370	2	3.1	0.24	0.77
50	Peach (Prunus persica)	86.9	46	0.5	0.1	12.0	0.6	0.5	8	0.6	22	880	8	0.9	0.05	0.02
51	Peanut, roasted (Arachis hypogaea)	2.6	559	26.9	44.2	23.6	2.4	2.7	74	1.9	393	0	(0)	16.2	0.13	0.30
52	Pear (Pyrus communis)	82.7	63	0.7	0.4	15.8	1.4	0.4	13	0.3	16	20	4	0.1	0.04	0.02
53	Pecan (Carya illinoensis)	3.0	696	9.4	73.0	13.0	2.2	1.6	74	2.4	324	50	2	0.9	0.11	0.72
54	Pepper, green (Capsicum annuum)	92.4	25	1.2	0.2	5.7	1.4	0.5	11	0.4	25	630	120	0.4	0.07	0.04
55	Pineapple (Ananas sativus)	85.3	52	0.4	0.2	13.7	0.4	0.4	16	0.3	11	130	24	0.2	0.03	0.08
56	Plantain (Musa paradisiaca)	66.4	119	1.1	0.4	31.2	0.4	0.9	7	0.7	30	10[4]	14	0.6	0.04	0.06
57	Plum (Prunus spp)	85.7	50	0.7	0.2	12.9	0.5	0.5	17	0.5	20	350	5	0.5	0.04	0.06
58	Potato (Solanum tuberosum)	77.8	83	2.0	0.1	19.1	0.4	1.0	11	0.7	56	20	25	1.2	0.04	0.11
59	Pruna (Prunus spp)	24.0	268	2.3	0.6	71.0	1.6	2.1	54	3.9	85	1890	3	1.7	0.16	0.10
60	Pumpkin (Cucurbita pepo)	90.5	31	1.2	0.2	7.3	1.3	0.8	21	0.8	44	(3400)	8	(0.6)	(0.08)	(0.05)
61	Radish (Raphanus sativus)	93.6	20	1.2	0.1	4.2	0.7	1.0	37	1.0	31	30	24	0.2	0.03	0.02
62	Raisin (Vitis vinifera)	24.0	268	2.3	0.5	71.2		2.0	78	3.3	129	50	Trace	0.5	0.08	0.15
63	Rice, brown (Oryza sativa)	12.0	360	7.5	1.7	77.7	0.6	1.1	39	2.0	303	(0)	(0)	4.6	0.05	0.32
64	Rice, white (O. sativa)	12.3	362	7.6	0.3	79.4	0.2	0.4	24	0.8	136	(0)	(0)	1.6	0.03	0.07
65	Rutabaga (Brassica campestris)	89.1	38	1.1	0.1	8.9	1.3	0.8	55	0.4	41	330	36	0.9	0.08	0.07
66	Rye (Secale cereale)	11.0	321	12.1	1.7	73.4	2.0	1.8	(38)	3.7	376	(0)	(0)	1.6	0.22	0.43
67	Soybean, mature, dried (Glycine soja)	7.5	331	34.9	18.1	34.8	5.0	4.7	227	8.0	586	110	Trace	2.3	0.31	1.07
68	Soybean, sprouts (G. soja)	86.3	46	6.2	1.4	5.3	0.8	0.8	48	1.0	67	180	13	0.8	0.20	0.23
69	Spinach (Spinacia oleracea)	92.7	23	2.3	0.3	3.2	0.6	1.5	81	3.0	55	9420	59	0.6	0.20	0.11
70	Squash, summer (Cucurbita pepo)	95.0	16	0.6	0.1	3.9	0.5	0.4	15	0.4	15	260	17	0.8	0.09	0.05
71	Squash, winter (C. maxima)	88.6	38	1.5	0.3	8.8	1.4	0.8	19	0.6	28	4950	8	0.5	0.12	0.05
72	Strawberry (Fragaria spp)	89.9	37	0.8	0.5	8.3	1.4	0.5	28	0.8	27	60	60	0.3	0.03	0.03
73	Sweatpotato (Ipomoea batatas)	68.5	123	1.8	0.7	27.9	1.0	1.1	30	0.7	49	7700	22	0.6	0.05	0.09
74	Tangerine (Citrus reticulata)	87.3	44	0.8	0.3	10.9	1.0	0.7	(13)	(0.4)	(23)	(420)	31	(0.2)	(0.03)	0.07
75	Tomato (Lycopersicon esculentum)	94.1	20	1.0	0.3	4.0	0.6	0.6	11	0.6	27	1100	23	0.5	0.04	0.06
76	Turnip (Brassica rapa)	90.9	32	1.1	0.2	7.1	1.1	0.7	40	0.5	34	Trace	28	0.5	0.07	0.05
77	Turnip greens (B. rapa)	89.5	30	2.9	0.4	5.4	1.2	1.8	259	2.4	50	9540	136	0.8	0.46	0.09
78	Walnut, English (Juglans regia)	3.3	654	15.0	64.4	15.6	2.1	1.7	83	2.1	380	30	3	1.2	0.13	0.48
79	Watermelon (Citrullus vulgaris)	92.1	28	0.5	0.2	6.9	0.6	0.3	7	0.2	12	590	6	0.2	0.05	0.05
80	Wheat (Triticum aestivum)	12.5	330	12.3	1.8	71.7	2.3	1.7	46	3.4	354	(0)	(0)	4.3	0.12	0.52

/1/ For yellow varieties, 150 I. U. /2/ Applicable to parad cucumber; for unpared, 1.2 mg iron and 260 I.U. vitamin A. /3/ Data also applicable to European grapes with the following modifications: food energy, 66 cal.; protein, 0.8 g; fat, 0.4 g; ash, 0.5 g. /4/ Applicable to white varieties; for yellow varieties, 1200 I. U. /5/ Year-round average. Recently harvested potatoes, 24 mg; after storage of 3 mo, 12 mg; after storage of 6 mo, 8 mg.

Table adapted from "Composition of Concentrate By-product Feeding Stuffs." Preliminary Report, Agricultural Board, National Research Council, 1956.

	Feeding Stuff	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	Ash %	N-Free Extract %	Calcium %	Cobalt mg/lb	Copper mg/lb	Iron %	Magnesium %	Manganese mg/lb	Phosphorus %	Sulfur %	Carotene mg/lb	Niacin mg/lb	Panto-thenic Acid mg/lb	Ribo-flavin mg/lb	Thiamine mg/lb
	Concentrates: Animal Origin																			
1	Blood, dried	91.8	80.1	1.6	0.6	5.4	4.1	1.10						0.68			11.4	2.2	1.3	0.1
2	Blood flour	90.8	82.2	1.0	0.6	4.8	2.2	0.45	0.04	3.7	0.28	0.04	2.9	0.37	0.60		13.0	2.4	1.9	0.2
3	Blood meal	90.5	79.9	1.6	0.8	5.6	2.6	0.28		4.5	0.38	0.22	2.4	0.22	0.38		14.3	0.5	0.7	
4	Bone meal, raw	93.2	26.2	4.6	1.4	57.8	3.2	22.14	0.05	8.5	0.04	0.35	3.9	10.35	0.12		1.9	1.0	0.6	0.1
5	Bone meal, steamed	95.2	12.1	3.2	1.7	71.8	6.4	28.98	0.03	7.4	0.08	0.61	13.8	13.59	0.22		1.9	1.1	0.4	0.2
6	Bone meal, sterilized	96.6	6.5	0.6	0.6	82.8	6.1	35.20				0.73		14.81						
7	Bone meal, unspecified	97.2	13.0	2.7	2.1	76.3	3.1	30.10	0.03	8.9	0.06	0.49	5.4	13.89	0.49		2.0	1.4	0.3	0.1
8	Buttermilk, dried	92.5	32.0	5.8	0.4	9.4	44.7	1.34				0.48	1.6	0.94	0.08		3.9	13.7	14.1	1.6
9	Cheese rind	74.5	31.3	27.4	0.1	4.0	11.7	0.86				0.02		0.49						
10	Crab meal	92.7	31.1	1.8	10.8	40.7	8.3	15.32		14.9	0.44	0.88	60.8	1.59	0.32			3.0	2.7	
11	Cracklings, dried	92.5	56.9	10.9	1.4	22.8	0.5	7.40					6.5	4.13					1.8	
12	Fish liver oil meal, cod	91.3	51.3	26.5	0.4	4.1	9.0	0.17					2.7	0.75			59.9	20.9	15.1	8.2
13	Fish meal, cod	94.0	58.9	1.6	0.1	29.9	2.9			1.3	0.017									
14	Fish meal, herring	92.3	70.6	7.5	0.4	10.8	3.0	2.94					4.5	2.20			40.4	5.2	4.1	
15	Fish meal, menhaden	92.2	61.3	7.7	0.7	19.6	2.9	5.49	0.09	3.8	0.06		11.7	2.81			25.4		2.2	0.3
16	Fish meal, salmon	93.0	58.0	9.6	0.3	16.7	8.4	5.44	0.03	5.4	0.02		3.6	3.26			11.3	3.1	2.6	0.4
17	Fish meal, sardine	93.2	65.5	4.3	0.8	15.7	6.9	4.90	0.08	9.2	0.03	0.10	10.1	2.77			28.2	4.2	2.7	0.2
18	Fish meal, unspecified	92.3	61.2	6.4	1.1	19.3	4.3	6.06	0.05	6.9	0.04	0.22	10.8	3.52	0.25		28.8	4.1	3.1	0.6
19	Fish meal, whitefish	91.6	63.2	4.4	0.7	21.7	1.6	7.87					6.5	3.61			31.7	4.0	4.1	0.8
20	Fish solubles product, dried	91.1	51.9	5.9	3.4	10.5	19.4	2.17						1.77			100.4	26.1	2.0	
21	Liver meal	92.6	66.5	15.1	1.3	6.0	3.7	0.50	0.06	40.5	0.06		4.0	1.25			92.9	20.5	21.0	0.1
22	Liver and glandular meal	93.4	65.1	16.0	1.5	5.8	4.9	0.66	0.09	44.1	0.05		3.3	1.14			73.4	48.2	18.5	1.2
23	Meat meal (meat scraps)	93.5	53.4	9.9	2.4	25.2	2.6	7.94	0.06	4.4	0.04	0.27	4.3	4.03	0.50		25.8	2.2	2.4	0.1
24	Meat meal, with bone	94.0	50.6	9.5	2.2	29.1	2.6	10.57	0.08	0.7	0.05	1.13	5.6	5.07			21.7	1.7	2.0	0.5
25	Milk albumin, dried	92.3	47.3	1.1	0.7	30.4	12.8	11.72						4.53			0.9	3.3	4.0	0.3
26	Milk, skimmed, dried	93.9	33.5	0.9	0.2	7.6	51.7	1.26	0.05	5.2	0.005	0.11	1.0	1.03	0.32		5.2	15.3	9.1	1.6
27	Milk, whole, dried	93.7	25.2	26.4	0.2	5.4	36.5	0.89		0.4	0.02		0.2	0.68		3.2	3.8	10.3	8.9	1.7
28	Shrimp meal	90.2	47.4	3.1	11.2	26.6	1.9	7.35			0.01	0.54	13.7	1.59					1.8	
29	Tankage, digester, unspecified	92.5	52.9	9.1	1.9	26.8	1.8	7.34		10.6	0.04		3.9	3.73			17.8	1.1	1.1	0.2
30	Tankage, digester, with bone	94.1	49.6	11.9	2.5	26.3	3.3	10.97						5.14						
31	Whale meat meal	92.1	78.9	6.8	0.5	4.0	1.9	0.25						0.56			47.6	1.2	3.8	0.6
32	Whale meal, with bone	92.4	54.0	9.8	1.4	25.8	1.4	8.29						4.16						
33	Whey, whole, dried	93.5	13.1	0.8	0.1	9.7	69.7	0.89	0.05	23.9	0.02		2.4	0.73	1.04		5.5	22.2	13.1	1.6
34	Whey, dried, cheese	94.7	13.1	0.5	0.3	8.3	72.5												8.1	
	Concentrates: Plant Origin																			
35	Apple pomace, dried	91.1	5.4	4.7	16.6	1.9	62.5	0.13			0.03	0.06	3.3	0.12	0.02					
36	Barley feed	90.3	12.6	3.0	8.2	3.6	62.9	0.06			0.01	0.16	13.9	0.43	0.05	0.2	28.9	3.5	1.0	2.7
37	Barley meal	90.8	14.7	1.0	2.4	5.5	67.2	0.05	0.00	4.3	0.01		7.7	0.70			16.6	6.6	1.8	2.1
38	Beet pulp, dried	90.8	9.1	0.6	19.4	3.6	58.1	0.68	0.05	5.7	0.03	0.27	15.9	0.10	0.20	0.1	7.4	0.7	0.3	0.2
39	Brewers grains, dried	92.4	25.9	6.2	14.5	3.6	42.2	0.27	0.03	9.7	0.03	0.14	17.1	0.50	0.31		19.7	3.9	0.7	0.3
40	Brewers yeast, dried	93.4	44.6	1.1	2.7	6.4	38.6	0.13	0.08	15.0	0.01	0.23	2.6	1.43	0.38	0.0	203.4	49.9	15.9	41.7
41	Buckwheat feed	94.4	15.7	4.0	14.3	4.5	54.9			5.7	0.01		37.1	0.48						
42	Citrus pulp, dried	90.1	6.6	4.6	13.0	6.0	59.9	1.96	0.08	2.6	0.02	0.16	3.1	0.12		0.1	9.8	5.9	1.1	0.7
43	Citrus seed meal	87.8	15.3	6.6	9.5	6.5	29.6	1.20		3.0	0.03	0.60	3.4	0.69						
44	Coconut oil meal, unspecified	91.2	20.6	7.5	11.7	6.4	45.0	0.18		4.3	0.68	0.36	34.3	0.61	0.34		17.5	2.4	1.9	0.5
45	Corn bran, unspecified	89.3	7.5	4.4	9.7	2.1	65.6	0.03				0.26	7.3	0.19	0.07				0.7	2.0
46	Corn distillers grains, dried	92.3	27.1	9.3	11.9	2.6	41.4	0.09	0.04	20.3	0.02	0.06	8.6	0.37	0.39	1.4	19.2	2.6	1.4	0.8
47	Corn meal, unspecified	87.8	9.0	3.6	1.6	1.2	72.4	0.02		1.4	0.004	0.11	2.8	0.24	0.08					
48	Corn oil meal, unspecified	90.9	21.5	3.7	11.2	1.9	52.6	0.09		5.0	0.02	0.28	4.1	0.56		0.2	24.1	1.6	2.5	3.2
49	Corn screenings	89.5	14.1	3.9	10.1	3.6	57.8												2.1	
50	Cottonseed feed	90.8	39.2	6.1	11.6	6.1	27.8	0.15				0.39		0.64	0.12					
51	Cottonseed flour	94.2	56.4	6.9	2.3	6.3	22.3	0.22									35.0		4.2	4.3
52	Cottonseed hull bran	90.7	3.1	0.8	38.7	2.3	45.8	0.09	0.02	1.9	0.005		7.6	0.10			3.5		0.2	0.1
53	Cottonseed oil meal, unspecified	92.5	40.6	6.1	10.1	6.1	29.6	0.20	0.07	8.9	0.03	0.56	9.3	1.09	0.41	0.1	17.0	5.7	2.9	3.7
54	Distillers grains, dried	91.6	29.1	8.9	11.5	3.1	39.0	0.20	0.04	21.5	0.03	0.12	15.7	0.55	0.45	3.5	21.0	5.2	1.7	1.1
55	Flaxseed screenings	91.4	15.8	9.4	12.4	6.7	47.1	0.37						0.43						

56	Grapefruit pulp, dried	87.6	7.6	4.8	13.4	4.9	56.9	1.30				0.38		0.16						
57	Linseed feed	90.5	33.8	4.8	9.5	6.0	36.4	0.43						0.65						
58	Linseed oil meal, unspecified	90.0	35.2	5.7	7.8	9.5	36.7	0.35	0.14	9.6	0.02	0.48	18.0	0.85	0.35	0.1	20.2	3.3	1.4	3.0
59	Mustard seed oil meal	94.4	31.1	6.2	11.1	6.4	39.6													
60	Oat feed	92.1	4.5	1.8	30.4	5.1	50.3	0.08				0.07		0.22	0.15					
61	Oatmeal	90.7	16.1	6.3	3.0	2.2	63.1	0.07	0.02	1.6	0.01		18.7	0.45			5.8	5.6	0.8	3.2
62	Orange pulp, dried	89.3	7.0	1.8	9.6	4.4	66.5	0.63						0.10						
63	Peanut oil meal, unspecified	93.5	42.6	8.3	11.0	5.2	26.4	0.16			0.03	0.22		0.56	0.10	0.1	79.0	24.2	2.1	3.1
64	Pineapple pulp, dried	89.1	4.2	1.5	17.0	3.1	63.3	0.21			0.03			0.11						
65	Potato meal, dehydrated	90.3	5.9	0.5	1.4	11.9	70.6												2.8	5.4
66	Potato pomace, dried	88.6	7.7	0.4	6.1	4.2	70.2												1.2	10.2
67	Rice bran, unspecified	90.6	13.5	15.1	10.9	10.9	40.2	0.06		5.9	0.12	0.95	189.9	1.82	0.18		137.8	10.7		
68	Rice meal	91.5	8.3	1.0	4.6	1.1	76.5						75.3							
69	Rice screenings	88.2	8.0	0.5	9.4	7.6	78.7	0.03				0.05		0.26			10.6			0.4
70	Rye bran	90.0	16.5	2.0	3.3	2.8	65.4													
71	Rye distillers grains, dried	93.0	22.4	6.4	13.8	2.6	47.8	0.13				0.17	8.4	0.41	0.44		7.7	2.4	1.5	0.6
72	Rye feed	89.7	17.2	3.4	4.6	3.8	60.7	0.07				0.23		0.59	0.04					
73	Rye middlings	89.8	17.1	3.1	5.8	3.4	60.4	0.06					20.0	0.63						
74	Safflower oil meal, unspecified	91.8	21.4	3.9	32.3	4.7	29.5	0.37					9.3	0.92						
75	Sesame oil meal, unspecified	93.3	41.3	8.4	6.1	11.8	25.7	2.07					48.8	1.38						
76	Sorghum bagasse	92.5	3.5	1.3	28.5	3.0	56.2									0.18		2.9	1.7	1.3
77	Sorghum gluten meal, unspecified	90.1	41.7	4.3	3.0	1.3	39.8	0.04				0.16	7.3	0.31			15.5	4.6	0.7	
78	Sorghum meal, milo sorghum	88.1	11.2	2.7	2.7	2.2	69.3	0.04				0.12	10.0	0.27						
79	Soybean oil meal, unspecified	90.1	44.7	3.2	5.5	5.9	30.8	0.26	0.03	8.2	0.02	0.25	14.0	0.61	0.19		15.1	7.0	1.6	1.6
80	Sunflower oil meal, unspecified	91.6	43.9	2.3	13.6	6.6	25.2	0.39				0.69	2.3	0.99		4.0	132.4	18.6	1.5	15.7
81	Tomato pomace, dried	92.0	21.7	13.0	29.0	4.2	24.1	0.28					21.5	0.57						
82	Wheat bran, unspecified	89.1	16.0	4.1	9.9	6.1	53.0	0.14	0.04	5.6	0.02	0.55	52.6	1.17	0.22	1.2	95.1	13.2	1.4	3.6
83	Wheat flour	89.1	15.8	2.9	2.6	2.1	65.7	0.03		2.1	0.002		20.4	0.28			19.0		0.4	2.7
84	Wheat germ oil meal	89.7	27.3	9.1	2.6	4.8	45.9	0.07	0.02	4.2	0.01		74.6	1.06		3.0	23.3	5.6	2.3	11.5
85	Wheat mill feed (mixed feed)	89.9	15.3	4.0	8.2	5.2	57.2	0.09	0.10	8.5	0.01	0.51	46.7	1.02			50.9	6.0	1.1	6.9
86	Wheat screenings	89.3	15.0	3.0	6.5	3.2	61.6	0.08					13.0	0.36						2.9
87	Wheat standard middlings, unspecified	89.7	17.2	4.6	7.6	4.4	55.9	0.15	0.04	10.0	0.01	0.37	53.8	0.91	0.05	1.4	44.8	9.0	0.9	5.8
88	Wheat distillers grains, dried	93.0	33.8	5.8	12.4	4.4	38.6	0.10						0.50		0.5	25.4	3.7	1.7	0.9
89	Yeast distillers molasses, dried	94.5	24.0	0.6	7.4	14.0	48.5										116.0	16.4	12.3	34.8
								Dry Roughages												
90	Alfalfa hay	90.5	14.8	2.0	28.9	8.2	36.6	1.47		3.67	0.03		20.48	0.24		11.40	17.38	8.08	6.17	1.32
91	Bluegrass hay, Kentucky	84.3	9.5	2.3	25.2	7.2	40.1	0.46		4.09	0.03		34.74	0.32				4.49		
92	Brome hay, smooth	86.8	5.7	4.4	28.5	8.2	40.0													
93	Brome grass hay	88.1	9.9	2.1	28.4	8.1	39.5	0.20					14.98	0.28			16.98			
94	Clover hay, alsike	88.9	12.1	2.1	27.0	7.8	39.9	1.15		2.41	0.04		47.13	0.23		47.22				
95	Clover hay, crimson	89.5	14.2	2.2	27.4	8.2	37.0	1.23					99.79	0.24						
96	Clover hay, Ladino	88.0	19.4	3.2	20.7	9.8	34.9	1.32			0.10		72.60	0.29						
97	Clover hay, red	88.1	11.8	2.6	27.2	6.4	40.1	1.35		4.00	0.03		48.35	0.19		4.04	16.89	4.49	4.10	0.86
98	Corn cobs	90.4	2.3	0.4	32.1	1.1	54.0							0.02						
99	Corn fodder	82.6	6.8	2.1	21.8	5.2	46.7	0.21						0.14		1.77				
100	Cowpea hay	90.4	18.6	2.6	23.3	11.3	34.6	1.37			0.08			0.29						
101	Grass hay	89.5	6.7	1.8	28.9	7.6	44.9	0.48			0.06			0.21						
102	Lespedeza hay, annual	89.2	12.7	2.4	26.7	5.2	42.2	0.98			0.03		59.15	0.18		22.43				
103	Oat hay	88.1	8.2	2.7	28.1	6.9	42.2	0.21			0.05		36.55	0.19						
104	Orchard grass hay	85.8	6.9	2.6	30.9	6.8	38.6	0.19						0.17						
105	Prairie hay	90.7	5.7	2.3	30.4	7.4	44.9	0.36						0.18		9.31				
106	Redtop hay	90.7	8.5	3.4	26.8	4.3	47.7	0.38		1.59	0.01		9.35	0.23						
107	Sorghum fodder, sweet	88.8	6.2	2.4	25.0	7.1	48.1	0.34					52.62	0.12		1.09				
108	Soybean hay	88.0	14.4	3.3	27.5	7.0	35.8	1.35						0.25		13.57				
109	Sudan grass hay	89.3	8.8	1.6	27.9	8.1	42.9	0.36			0.01		37.05	0.26		37.23				
110	Sweet clover hay	92.2	15.8	1.6	24.7	10.8	39.3	1.25		4.09	0.01		48.53	0.23						
111	Timothy hay	89.0	6.5	2.4	30.2	4.9	45.0	0.23						0.20		5.32	15.48		4.09	0.59
112	Vetch hay, common	85.2	18.7	1.8	22.2	7.8	34.7	1.13		4.00	0.03		21.52	0.32						
113	Wheat hay	90.4	6.1	1.8	26.1	6.4	50.0	0.14						0.18						
								Silages												
114	Alfalfa	25.3	4.6	0.9	8.2	2.3	9.3	0.35		1.09	0.007		5.99	0.08		21.11				
115	Corn	23.8	1.8	0.7	6.4	1.5	13.4	0.10		0.59	0.003		8.80	0.06		6.40				
116	Grass	24.3	3.1	0.8	7.3	2.6	10.5									24.33				

158. FOODS OF ANIMAL ORIGIN: COMPOSITION

Values are per 100 grams of edible portion of fresh, uncooked food, unless otherwise specified. Values based on inadequate evidence are enclosed in parentheses.

	Food	Water	Food Energy	Protein	Fat	Carbohydrate		Ash	Ca	Fe	P	Vitamin A	Ascorbic acid	Niacin	Riboflavin	Thiamine
						Total	Fiber									
		g	Cal	g	g	g	g	g	mg	mg	mg	I. U.	mg	mg	mg	mg
	Dairy Products															
1	Butter	15.5	716	0.6	81	0.4	0	2.5	20	0	16	3300[1]	0	0.1	0.01	Trace
2	Buttermilk	90.5	36	3.5	0.1	5.1	0	0.8	(118)	0.1	93	Trace	1	0.1	0.18	0.04
3	Cheese: Cheddar	37	398	25.0	32.2	2.1	0	3.7	725	1.0	495	1400	(0)	Trace	0.42	0.02
4	Cottage	76.5	95	19.5	0.5	2.0	0	1.5	96	0.3	189	(20)	(0)	(0.1)	0.31	0.02
5	Cream	51	371	9.0	37.0	2.0	0	1.0	68	0.2	97	(1450)	(0)	0.1	0.22	(0.01)
6	Swiss	39	370	27.5	28.0	1.7	0	3.8	925	0.9	563	1450	(0)	(0.1)	0.40	0.01
7	Cream, light	72.5	204	2.9	20.0	4.0	0	0.6	97	0.1	77	830	1	0.1	0.14	0.03
8	Milk, cow: whole	87	68	3.5	3.9	4.9	0	0.7	118	0.1	93	(160)	1	0.1	0.17	0.04
9	Skimmed	90.5	36	3.5	0.1	5.1	0	0.8	123	0.1	97	Trace	1	0.1	0.18	0.04
10	Milk, goat	87.4	67	3.3	4.0	4.6	0	0.7	129	0.1	106	(160)	1	0.3	0.11	0.04
	Meats															
11	Beef: chuck	65	224	18.6	16	0	0	0.9	11	2.8	167	(0)	0	4.5	0.17	0.08
12	Flank	61	247	19.9	18	0	0	0.9	12	3.0	186	(0)	0	4.8	0.18	0.09
13	Hamburger	55	321	16.0	28	0	0	0.8	9	2.4	128	(0)	0	3.8	0.14	0.07
14	Heart	77.6	108	15.7	4.8	0.7	0	1.1	9	4.6	203	30	6	7.8	0.89	0.58
15	Kidney	74.9	141	15.0	8.1	0.9	0	1.1	9	7.9	221	1150	13	6.4	2.55	0.37
16	Liver	69.7	136	19.7	3.2	6.0	0	1.4	7	6.6	358	43,900	31	13.7	3.33	0.26
17	Porterhouse	58	296	16.4	25	0	0	0.8	10	2.5	134	(0)	0	3.9	0.15	0.07
18	Rib roast	59	282	17.4	23	0	0	0.8	10	2.6	149	(0)	0	4.2	0.15	0.07
19	Round	69	182	19.5	11	0	0	1.0	11	2.9	180	(0)	0	4.7	0.17	0.08
20	Rump	55	322	16.2	28	0	0	0.8	9	2.4	131	(0)	0	3.9	0.14	0.07
21	Sirloin	62	254	17.3	20	0	0	0.9	10	2.6	147	(0)	0	4.2	0.15	0.07
22	Tongue	66	207	16.4	15.0	0.4	(0)	0.9	9	2.8	187	(0)	(0)	5.0	0.20	0.12
23	Brains	78.9	125	10.4	8.6	0.8	0	1.4	16	3.6	330	0	18	4.2	0.26	0.23
24	Lamb: leg roast	63.7	235	18.0	17.5	0	0	0.9	10	2.7	213	(0)	0	5.2	0.22	0.16
25	Liver	70.8	136	21.0	3.9	2.9	0	1.4	8	12.6	364	50,300	33	16.5	3.28	0.41
26	Kidney	77.8	105	16.6	3.3	1.0	0	1.3	13	9.2	237	(1150)	13	7.4	2.42	0.51
27	Shoulder roast	58.3	295	15.6	25.3	0	0	0.8	9	2.3	155	(0)	0	4.5	0.19	0.14
28	Pork: bacon	20	630	9.1	65	1.1	0	4.3	13	0.8	108	(0)	0	1.9	0.12	0.38
29	Ham, fresh	53	344	15.2	31.0	0	0	0.8	9	2.3	168	(0)	0	4.0	0.18	0.74
30	Ham, smoked	42	389	16.9	35.0	(0.3)	0	5.4	10	2.5	136	(0)	0	4.0	0.19	0.70
31	Heart	76.8	117	14.9	6.4	0.4	0	1.1	35	2.7	132	30	6	6.0	1.24	0.43
32	Kidney	77.1	114	16.3	4.6	0.8	0	1.2	11	8.0	246	130	13	9.8	1.74	0.58
33	Liver	72.3	134	19.7	4.8	1.7	0	1.5	10	18.0	362	14,200	23	16.7	2.98	0.40
34	Loin or chops	58	296	16.4	25	0	0	0.9	10	2.5	186	(0)	0	4.3	0.19	0.80
35	Salt pork, fat	8	783	3.9	85	0	(0)	3.5	Trace	0.6	Trace	(0)	0	(0.9)	(0.04)	(0.18)
36	Sausage	41.9	450	10.8	44.8	0	0	2.1	6	1.6	100	(0)	0	2.3	0.17	0.43
37	Spare rib, medium	53	351	14.8	32	0	0	0.8	8	2.2	158	(0)	0	3.8	0.17	0.71
38	Rabbit, domesticated	54	122	16	6	0	0	0.8	15	1.0	271			9.9	0.04	0.06
39	Seal, canned	66	183	19.1	10.6	1.4				11.4				4.9	0.09	0.04
40	Veal: cutlet	70	164	19.5	9.0	0	0	1.0	11	2.9	200	(0)	0	6.5	0.26	0.14
41	Leg roast	68	186	19.1	12.2	0	0	1.0	11	2.9	206	0	0	6.3	0.27	0.17
42	Liver	71	141	19.0	4	4	0	1.3	6	10.6	343	22,500	36	16.1	3.12	0.21
43	Shoulder roast	70	173	19.4	10.0	0	0	1.0	11	2.9	199	(0)	0	6.5	0.26	0.14
44	Stew meat	64	231	18.3	17.0	0	0	0.9	11	2.7	182	(0)	0	6.1	0.24	0.13
45	Venison	73	140	20	6.0	0	0	1.0	12	3.0	216					0.14
	Poultry and Eggs															
46	Chicken: broiler	71.2	151	20.2	7.2	0	0	1.1	14	1.5	200	(0)	(0)	10.2	0.16	0.08
47	Heart	69.6	197	20.5	7.0	1.6	0	1.3	23	1.7	142	30	6	5.2	0.91	0.12
48	Liver	69.6	141	22.1	4.0	2.6	0	1.7	16	7.4	240	32,200	20	11.8	2.46	0.20
49	Roaster	66.0	200	20.2	12.6	0	0	1.0	14	1.5	200	(0)	(0)	8.0	0.16	0.08
50	Egg, whole	74.0	162	12.8	11.5	0.7	0	1.0	54	2.7	210	1140	0	0.1	0.29	0.10
51	Egg white	87.8	50	10.8	0	0.8	0	0.6	6	0.2	17	(0)	0	0.1	0.26	0
52	Egg yolk	49.4	361	16.3	31.9	0.7	0	1.7	147	7.2	586	3210	0	Trace	0.35	0.27
53	Duck	54	326	16.1	29	0	0	1.3	9	2.4	172	0	0	6.1	0.23	0.16
54	Goose	50	354	16.4	32	0	0	0.9	9	2.4	176		9	5.6		0.15
55	Squab	58	279	18.6	22.1	0	0	1.5	12	3.0	217					
56	Turkey	58.3	268	20.1	20.2	0	0	1.0	23	3.8	320	Trace	(0)	8.0	0.14	0.09
	Fish and Shellfish															
57	Bluefish	74.6	124	20.5	4.0	0	0	1.2	23	0.6	243			1.9	(0.09)	(0.12)
58	Clam	80.3	81	12.8	1.4	3.4		2.1	(96)	(7.0)	(139)	110		(1.6)	0.18	0.10
59	Cod	82.6	74	16.5	0.4	0	0	1.2	10	0.4	194	0	2	2.2	0.09	0.06
60	Crab	80.0	86	16.1	1.6	0.6		1.7	(39)	(0.8)	(160)			2.7	0.06	0.14
61	Eel	71.6	162	18.6	9.1	0	0	1.0	18	0.7	202	1800		1.4	0.37	0.28
62	Flounder	82.7	68	14.9	0.5	0	0	1.3	61	0.8	195			1.7	0.05	0.06
63	Haddock	80.7	79	18.2	0.1	0	0	1.4	23	0.7	197			2.4	0.08	0.05
64	Halibut	75.4	126	18.6	5.2	0	0	1.0	13	0.7	211	440		9.2	0.06	0.07
65	Herring, Atlantic	67.2	191	18.3	12.5	0	0	2.7	1.1	256	110			3.4	0.15	0.02
66	Herring, Pacific	79.6	94	16.6	2.6	0	0	1.3				100		(2.2)	0.22	0.02
67	Lobster	79.2	88	16.2	1.9	0.5	0	2.2	61	0.6	184			(1.9)	0.06	(0.13)
68	Mackerel	68.1	188	18.7	12.0	0	0	1.2	5	1.0	239	(450)		8.4	0.35	0.15
69	Oyster	80.5	84	9.8	2.1	5.6	0	2.0	94	5.6	143	320		1.2	0.20	0.15
70	Perch, yellow	80	88	18.7	0.9	0	0	1.2	20	1.0	215			1.7	0.07	0.09
71	Salmon	63.4	223	17.4	16.3	0	0	1.0		(0.9)	(289)	310	9	7.2	0.23	0.10
72	Sardine, canned	57.4	214	25.7	11.0	1.2		(4.7)	386	2.7	586	220	(0)	4.8	0.17	0.02
73	Scallop	80.3	78	14.8	0.1	3.4	0	1.4	26	1.8	208	0		1.4	0.10	(0.04)
74	Shad	70.2	168	18.7	9.8	0	0	1.4	0	0.5	260			(8.4)	0.24	(0.19)
75	Shrimp, canned	66.2	127	26.8	1.4	0	0	5.8	115	3.1	260	60	(0)	2.2	0.03	0.01
76	Swordfish	75.8	118	19.2	4.0	0	0	1.3	19	0.9	195	1580		9.1	0.05	0.05
77	Tuna, canned	60.0	198	29.0	8.2	0	0	2.7	(8)	1.4	(351)	80	(0)	12.8	0.12	0.05
78	Whitefish	70	156	22.9	6.5	0	0	1.6	25	1.3	263			(4.2)	(0.09)	(0.09)

[1] Year-round average.

159. FERTILIZERS: CHEMICAL ELEMENT COMPOSITION AND NEUTRALIZING ACTION

Values are g per 100 g of fertilizers, and where composition of fertilizer material is variable, they are averages of several determinations for total element present (cf Fn 2 for exceptions in case of phosphorus and potassium).

	Fertilizer Materials	Ca	Mg	N	P^{2}	K^{2}	S	Action
	Inorganic Fertilizers							
	N Materials							
1	Ammonia, anhydrous			82				Acidic
2	Ammonia solution[3]			21-25				Acidic
3	Ammonium chloride			24				Acidic
4	Ammonium nitrate			32-34				Acidic
5	Ammonium sulfate			20			24	Acidic
6	Calcium ammonium nitrate (A.N.L.)	7.1-14	0-6.5	20				Neut.
7	Calcium cyanamide[4]	39		21			0.4	Basic
8	Calcium nitrate	20		16				Basic
9	Calcium nitrate-urea[5]	9.3		34			1	Acidic
10	Sodium nitrate			16				Basic
11	Urea (Uramon)			42-46				Acidic
12	Urea-ammonia liquor			46				Acidic
	P Materials							
13	Basic slag, Beasemer	34	2.4		7		0.2	Basic
14	Basic slag, open-hearth	32	3		2.2-6.5		0.2	Basic
15	Phosphate rock, defluorinated	20-30			7.9-10			Basic
16	Phosphoric acid, liquid				24		1.4[6]	Acidic
17	Superphosphate, double	12-14	0.3		19-21		1	Neut.
18	Superphosphate, ordinary	18-21	0.3		6.1-8.7		11-12	Neut.
	K Materials							
19	Alunite, calcined	2.9	0.3			4.6	2	
20	Kainite	0.4-3.6	0-9			10-18	0.4-10	Neut.
21	Manure salts	0-0.7	0-3.6			21-33	0-5.2	Neut.
22	Potassium carbonate					54		Basic
23	Potassium chloride	0-2.1	0-1.8			40-51	0-2.8	Neut.
24	Potassium magnesium sulfate	0-4.6	3.6-12			17-25	13-22	Neut.
25	Potassium sulfate	0-1.8	0-1.2			40-43	16-19	Neut.
	N-P, N-K Materials							
26	Ammoniated superphosphate, double	12-14	0.3	4-6	18-21		1	Acidic
27	Ammoniated superphosphate, ordinary	17-21	0.3	2-5	5.9-8.5		11-12	Acidic
28	Monoammonium phosphate[7,8]	1.1	0.3	11	21		2.4	Acidic
29	Monoammonium phosphate-ammonium sulfate[7,9]	0.4		16	8.7		15	Acidic
30	Urea-superphosphate			7	6.5			Acidic
31	Potassium ammonium chloride[10]			13		18		Acidic
32	Potassium nitrate	0.4	0.3	13		37		Basic
33	Sodium potassium nitrate			15		12		Basic
	N-P-K, P-K Materials							
34	Ammonium potassium phosphate			5.5	24	15		Acidic
35	Monopotassium phosphate				23	29		Neut.
36	Potassium metaphosphate	0.4			24	32		Neut.
	Organic Fertilizers							
	Animal By-products							
37	Blood, dried	0.4		13	0.9	0.8		Acidic
38	Bone meal, raw	22	0.6	4	9.8		0.2	Basic
39	Bone meal, steamed	24	0.3	2.5	11		0.2	Basic
40	Fish scrap or meal, dried	6.1	0.3	9.5	3.1		0.2	Acidic
41	Hoof and horn meal	1.8		14	0.4		0.8	Acidic
42	Tankage, animal	11	0.3	7	4.4	0.4	0.4	Basic
43	Tankage, process	0.4		9	0.2		0.4	Acidic
44	Whale guano or tankage	6.6	0.3	9.5	2.8			Acidic
45	Wool waste	0.4		3.5	0.2	1.7		
	Animal Excreta							
46	Guano, bat	5.4	0.3	8.5	2.2	1.2	0.8	Acidic
47	Guano, Peruvian	7.9	0.6	13	5.2	2.1	1.4	Acidic
48	Manure, cattle	2.9	0.6	2	0.7	1.7	0.2	Basic
49	Manure, horse	1.1	0.6	2	0.7	1.2	0.2	Basic
50	Manure, poultry	2.9	0.6	5	1.3	1.2	0.8	Acidic
51	Manure, sheep	3.6	1.2	2	0.7	2.5	0.6	Basic
52	Sewage sludge, activated	1.8	0.9	6	1.3	0.4	0.4	Acidic
53	Sewage sludge, dried	1.8	0.3	2	0.9		0.2	Acidic
	Plant Residues							
54	Castor pomace	0.4	0.3	5.5	0.7	1.2		Acidic
55	Cocoa shell meal	1.1	0.3	2.5	0.4	1.7		Basic
56	Cottonseed hull, ash	6.8	3		2.4	22	1	Basic
57	Cottonseed meal	0.4	0.3	7	1.3	1.7	0.2	Acidic
58	Garbage tankage	3.2	0.3	2.5	1.3	0.8	0.4	Basic
59	Kelp, Pacific	1.1	0.6	2.5	0.7	12	1	
60	Linseed meal	0.4	0.6	5.5	0.9	1.2	0.4	
61	Peat, moisture-free	0.7	0.3	2			0.2	Acidic[11]
62	Seaweed	2.1	0.6	1.5	0.2	1.7	1.4	
63	Soybean meal	0.4	0.3	7	0.7	2.1	0.2	Acidic
64	Tobacco, ash	16	3.6		1.3	19		Basic
65	Tobacco stems	3.6	0.3	2	0.2	5	0.4	Basic
66	Wood ash, commercial	23	2.1		0.9	4.2	0.4	Basic

/1/ For conversion of values for elements to those for commonly used oxides of the elements, the following factors are employed: Ca x 1.399 = CaO, Mg x 1.658 = MgO, P x 2.291 = P_2O_5, K x 1.205 = K_2O; S x 2.497 = SO_3. /2/ Values forphosphorus (from inorganic fertilizers) are applicable to available phosphorus, i. e., amount of phosphorus soluble in water or in solutions of salts or acids. Values for potassium(from inorganic fertilizers) are applicable to water-soluble potassium. /3/ Includes ammonium hydroxide, aqua ammonia, ammonia liquor, "B" liquor. /4/ Also known as Cyanamid, Nitrolime. /5/ Also known as Calurea. /6/ Sulfate content arises from H_2SO_4 process used in production of P_2O_5. /7/ Data applicable to material prepared with P_2O_5 manufactured by the H_2SO_4 process. Material made with electric furnace P_2O_5 has higher purity. /8/ Also known as Ammo-Phos A. /9/ Also known as Ammo-Phos B. /10/ Also known as Potazote. /11/ Some peats may be basic.

160. NUTRIENTS: STABILITY AND LABILITY

Nutrients are especially sensitive to the reaction (pH) of the solvent, and to exposure to air, light and heat. Unless otherwise specified, reference is made to the properties of the nutrient in aqueous solution. Where no footnote is given, the stability of the nutrient is estimated on the basis of its chemical composition, or other well-known properties.
S = stable, i.e., nutrient exhibits no appreciable breakdown under the conditions specified. L = labile, i.e., nutrient exhibits appreciable decomposition under the conditions specified. +++ = appreciable loss; + = slight loss.

	Nutrient	pH?	<pH?	>pH?	Oxygen	Light	Heat	% Loss in Cooking[1]
	Vitamins							
1	A	S[2]			L[2]	L	S[2]	10-30
2	Ascorbic acid	L[3]	S[3]	L[3]	L[3]	L[3]	L[3]	20-80
3	Biotin	S	S	S	S	S	S	0-72
4	Choline	S	S	S	L	S	S	
5	Cobalamin	S[4]	S[4]	S[4]	L	L	S[4]	
6	D_2[5]	S		L	L[6]	L	+++	
7	E	S	S	S	L[7]	L[8]	S[7]	50[7]
8	Folic acid group	L	L[10]	S[10,11]	L[11]	L[12]	S[10]	0-97
9	Inositol	S	S[13]	S	S	S	S[13]	0-95
10	K	S	S	L[14]	S	L	S	
11	Niacin[15]	S	S	S	S	S	S	0-72
12	Pantothenic acid	S	L	L	S	S	L	0-44
13	p-Aminobenzoic acid	S	S[16]	S[17]	L	S	S	
14	Pyridoxine group	S[18]	S[18]	S[18]	S[19]	L	S[18]	
	Vitamins (concluded)							
15	Riboflavin	S[20]	S[21]	L	S[21]	L[22]	S[20]	0-48
16	Thiamine	L[23]	S[24]	L[25]	L[26]	S[24]	L[24,25]	25-45
17	Unsaturated fatty acids	S	S	L	L[27]	L[27]	S	<10
	Amino acids[28]							
18	Isoleucine	S	S	S	S	S	S	+
19	Leucine	S	S	S	S	S	S	+
20	Lysine	S	S	S	S	S	S	+
21	Methionine	S	S	S	S	S	S	+
22	Phenylalanine	S	S	S	S	L[29]	S	+
23	Threonine	S	S	L	S	S	S	+
24	Tryptophan	S	L	S	S	L[29]	S	+
25	Valine	S	S	S	S	S	S	+
26	Inorganic salts	S	S	S	L[30]	S	S	+

/1/ Nutrient loss expressed as percentage of quantity of nutrient present before cooking. /2/ Loses biological activity if heated in presence of oxygen for 5.5 hours. /3/ Decomposes in light; decomposition accelerated by oxygen, metal ions. /4/ Stable in boiling water at pH 7 for 2 hours. /5/ Stable in dry propylene glycol more than three years when stored in amber bottles. /6/ Activity lost in mixed feeds, also under prolonged irradiation in presence of oxygen. /7/ In absence of oxygen, stable to heat up to 200°C. /8/ Tocopherols stable to visible light, but readily destroyed by UV. /9/ Deep fat frying and baking result in appreciable destruction. /10/ No destruction at pH 6.8 and 100°C for 30 minutes. /11/ Aeration at pH 10 causes partial inactivation. /12/ Rapidly inactivated by light. /13/ Stable to refluxing with 10% HCl for 6 hours, to alkali and to a variety of chemical agents. /14/ Sensitive to alkali. /15/ Nicotinamide is partially hydrolyzed by alkali and acid, but the product, nicotinic acid, having the same vitamin activity as nicotinamide retains its biological activity. /16/ Only 15% destruction on autoclaving solutions in 6N H_2SO_4 for 60 minutes. /17/ Long treatment with alkali results in destruction. /18/ Pyridoxine not destroyed by heating with 5N acid or alkali at 100°C, or autoclaving in acid or alkali; pyridoxal and pyridoxamine stable in hot acid, but pyridoxal partially decomposed by hot alkali. /19/ Oxidized only by such strong agents as hot HNO_3, H_2O_2. /20/ Stable in neutral or acid solutions. /21/ 1/2% decomposed per month at pH 5.0 at 27°C. /22/ 50% of the riboflavin of milk destroyed when exposed to sunlight for 2 hours. /23/ 96.4% destroyed at 100°C at pH 7 in 3 hours. /24/ No destruction in 1% HCl in 7 hours at 100°C. /25/ 100% destroyed in 15 minutes at pH 9 at 100°C. /26/ Unstable in presence of air. /27/ Sensitive to light and air oxidation. /28/ Most amino acids undergo racemization in alkaline solutions, but they are otherwise stable. /29/ Modified by UV. /30/ Oxidation of some inorganic salts of lower valence to higher valence states (e.g., ferrous to ferric iron) when exposed to atmospheric oxygens.

161. NUTRIENT LOSSES IN COOKING

Values are rough approximations of the percentage of nutrients lost in various types of cooking. I = baking; II = boiling; III = braising; IV = broiling; V = double boiler; VI = pressure saucepan; VII = roasting; VIII = steaming; IX = stewing; X = discarding water or dripping; XI = retaining water or dripping; XII = mashed; XIII = frying.

	Food Type	Minerals				Vitamins[1]						Food Type	Minerals				Vitamins[1]					
		Cooking Method	Ca	Fe	P	A	C	Niacin	Ribo-flavin	Thia-mine			Cooking Method	Ca	Fe	P	A	C	Niacin	Ribo-flavin	Thia-mine
1	Cabbage[2,3]	II;XI					10	25				22	II;XI							15		
2		II;X					40	25	15			23	Potatoes[2] (concluded)	II;X	15	10	0		20	20	25	20
3		VI					30					24		XII					50			
4		VIII					50	20	15			25		VI					30	0	5	5
5	Cereals[4]	V;15 min						0	0	0		26		VIII					15			
6		V;30 min						0	0	2		27	Roots and bulbs[2,9]	II;XI				5	10	15	15	
7		V;120 min						0	0	8		28		II;X	1	5	0		65	35		
8	Corn[2]	II					35	15	10	20		29		VI	25	5	15					
9	Flowers and shoots[2,5]	II;XI				0	10	15		1		30		VIII								
10		II;X	20	5	15	0	30	25	35	40		31	Squash[2]	VIII					55			50
11		VI					30					32	Meats[10]	III;XI						10	5	40
12		VIII				0	25	15	15	15		33		III;X						35	25	55
13	Leafy[2,6]	II;XI					25	20	10	5		34		IV;XI						5	10	25
14		II;X	20	5	15		50	25	30	30		35		IV;X						20	20	30
15		VI					50					36		VII;XI						5	10	30
16		VIII					60	10	15	15		37		VII;X						20	15	40
17	Legumes, fresh[2,7]	II;XI					5	5	0	10		38		IX;XI						0	0	50
18		II;X	0	1	5		15	40	20	20		39		IX;X						50	30	75
19		VIII					10	15	0	5	5	40	Fish[10]	XIII						5	10	
20	Potatoes[2]	I						25				41		VIII						5	0	
21		II[8]						0														

/1/ Loss of water soluble vitamins increases in proportion to amount of cooking water used. /2/ Cooked immediately, without standing after preparation. /3/ Also brussels sprouts. /4/ Rolled oats. /5/ Asparagus, broccoli, cauliflower. /6/ Kale, spinach, Swiss chard. /7/ Beans, peas. /8/ Boiled in jackets. /9/ Beets, carrots, onions, parsnips, turnips. /10/ Unspecified.

162. NUTRITIVE VALUE PER POUND: SELECTED FOODS AND GROUPS OF FOODS[1]

	Item	Food Energy Cal	Protein g	Fat g	Carbohydrate g	Calcium mg	Iron mg	Vitamin A I.U.	Thiamine mg	Riboflavin mg	Niacin mg	Ascorbic Acid mg
1	Meat, poultry, fish	920	63	70.9	0.3	60	9.1	1600	0.99	0.83	18.9	3
2	Meat	1050	64	84.0	0.4	40	10.8	1900	1.30	0.97	17.7	5
3	Poultry, fish	600	59	38.3	0.1	100	4.9	800	0.24	0.48	21.8	0
4	Eggs	655	52	46.5	2.8	220	10.9	4600	0.39	1.17	0.3	0
5	Leafy, green, and yellow vegetables	130	8	1.0	26.5	180	3.9	9200	0.31	0.34	2.4	101
6	Leafy vegetables	60	6	0.9	11.5	220	3.6	8900	0.17	0.38	1.6	91
7	Other green and yellow vegetables	150	9	1.0	30.9	170	4.0	9300	0.34	0.33	2.7	104
8	Citrus fruit, tomatoes	150	4	1.1	35.4	70	1.9	2400	0.24	0.13	1.8	128
9	Citrus fruit	170	3	0.8	42.8	80	1.2	400	0.23	0.08	0.8	160
10	Tomatoes	120	5	1.6	25.5	50	2.7	5000	0.24	0.19	3.2	86
11	Other vegetables and fruit	210	4	1.6	50.9	70	2.0	1200	0.15	0.16	1.6	33
12	Fruit, fresh, canned and frozen	215	2	1.6	54.4	40	1.6	1600	0.13	0.13	1.3	28
13	Fruit, dried	1145	11	2.6	301.8	320	14.5	3800	0.51	0.50	5.7	9
14	Vegetables	155	6	1.6	33.9	90	2.1	500	0.17	0.19	1.9	41
15	Potatoes, sweetpotatoes	330	8	0.5	75.2	50	2.7	2200	0.40	0.15	4.3	65
16	Dry beans and peas, nuts	1920	104	85.7	211.7	600	24.7	100	2.56	0.93	26.2	5
17	Dairy products excluding butter (milk equivalent)	300	16	16.8	20.8	530	0.4	700	0.14	0.74	0.4	5
18	Non-fat solids (skim)	1645	162	4.5	236.1	5900	2.6	200	1.60	8.88	5.2	32
19	Milk, fluid whole	310	16	17.7	22.2	540	0.3	700	0.16	0.78	0.5	6
20	Cheese, all kinds	1350	105	98.7	9.4	2350	3.5	4300	0.10	1.74	0.2	0
21	Flour and cereal products, including enrichment	1650	47	5.7	346.7	80	10.2	100	1.41	0.79	11.5	0
22	Bread, white enriched (4% non-fat milk solids)	1245	39	14.5	235.2	360	8.0	0	1.10	0.70	10.0	0
23	Fats and oils, including bacon and salt pork	3540	11	391.0	1.6	35	1.0	3700	0.45	0.13	2.2	0
24	Butter and margarine	3260	3	367.7	1.8	90	0	15,000	0	0	0	0
25	Other, excluding bacon and salt pork	4054	0	454.0	0	0	0	0	0	0	0	0
26	Sugars and sirups	1695	Trace	0	437.7	35	2.1	0	Trace	0.01	0.1	Trace

/1/ Nutritive values used in basic computations are from Watt, B. K., and Merrill, A. L., U. S. Dept. Agr. Handbook 8, 1950. Except for eggs, non-fat milk solids (skim), fluid whole milk and white bread, enriched, these average nutritive values per pound are weighted by the relative quantities of foods within each of the groups estimated by the Agricultural Economics Division, Agricultural Marketing Service, as disappearing during 1952 into retail channels for civilian consumption. No deductions have been made for losses during cooking except those taken into account in Handbook 8, as, for example, in canned vegetables.

163. NUTRIENTS: SELECTED SOURCES

Foods listed are important sources of nutrients indicated. Values are per 100 grams of edible portion of fresh uncooked food, unless otherwise specified.

	Nutrient	Sources and Nutritive Value
1	Food energy, Cal	Cheese (except cottage): 300-400; cooking and table fats, salad oils: 700-900; grain products, dry: 330-390; treenuts and peanut: 560-700; salt pork, bacon, and other fat meats: 600-800; sugars: 370-385.
2	Protein, g	Egg: 13; grains: 8-14; legumes, dry, mature: 21-35; meat, poultry, fish: 16-20; milk: 3-4.
3	Carbohydrate, g	Fruit, dried: 67-73; grains: 70-80; legumes, dry, mature (except soybean): 60-64; potato, sweetpotato: 19-28; sugars: 90-100.
4	Fat, g	Cheese (except cottage): 25-37; cooking and table fats, salad oils: 81-100; cream: 20-35; nuts: 54-75; salt pork, bacon, other fat meats: 55-85.
5	Vitamin A, I.U.	Butter, margarine: 3300; carrot: 12,000; greens, all kinds: 3000-9500; liver, all kinds: 14,200-50,500; sweetpotato: 7700.
6	Ascorbic acid, mg	Various berries: 16-60; citrus fruit: 40-50; cantaloupe, honeydew: 23-33; green pepper: 120; broccoli, cabbage, cauliflower: 50-118; greens: collards, kale, mustard, turnip: 100-136; spinach: 59; potato, sweetpotato: 17-22; tomato: 23.
7	Choline, mg	Bean, snap: 340; pea: 260; egg yolk: 1130-1700; liver: 470-700; peanut: 160-170; soybean: 300-340; spinach: 240; wheat germ: 400.
8	Vitamin B_{12}	Liver and kidney: high; milk, muscle meats, fish: medium; corn, soybean, wheat, yeast: low.
9	Vitamin D, I.U.	Egg yolk, dried: 265; fish[1]: pilchard: 745; salmon: 314; sardine: 1379; fish[2]: herring: 315; mackerel: 1100; shrimp: 150; liver, all kinds: 8-58.
10	Tocopherol, mg	Bean, navy, dry: 3.6; butter: 2.4; margarine: 54; egg, whole: 2; corn oil: 87; peanut oil: 22; soybean oil: 140.
11	Folic acid, µg	Asparagus: 85-142; broccoli: 34; bean, navy, dry: 129; corn, sweet: 9-70; cheese, cottage: 21-46; date, dry: 25; greens: collards, kale, mustard: 20-115; liver: 220-290; nuts: 27-77.
12	Vitamin K, µg	Cabbage, cauliflower: 250-275; liver, pork: 115-130; oats: 75; soybean: 190; spinach: 334; wheat bran: 80.
13	Niacin, mg	Beef, lamb, pork: 2.6-5.2; fish[3], poultry, veal: 5.6-10.5; liver, all kinds: 13.7-16.9; peanut: 16.2; wheat, other grain products, whole or enriched: 2-5.
14	Pantothenic acid, mg	Bean, lima, dry: 0.8; kidney, lamb: 4.3; broccoli: 1.4; mushroom: 1.7; brains, beef: 2.1-2.5; egg: 2.7; liver, beef and pork: 5.7-8.2; peanut, roasted: 2.5; wheat bran: 2.4.
15	Pyridoxine, mg	Banana; cabbage; peanut, roasted; sweetpotato: 0.3; bean, lima, dry: 0.5; halibut: 0.1; liver, beef: 0.8; pork loin: 0.1-0.3; wheat, whole: 0.2; wheat germ: 0.6.
16	Riboflavin, mg	Egg: 0.29; greens: collards, kale, turnip: 0.26-0.46; liver, all kinds: 2.46-3.96; meat, poultry: 0.12-0.26; milk: 0.17.
17	Thiamine, mg	Legumes, dry, mature: 0.48-1.07; treenuts and peanut: 0.25-0.86; pork: 0.48-0.80; brown rice, rye, corn: 0.32-0.43; whole wheat, oatmeal: 0.40-0.60.
18	Calcium, mg	Cheese: cheddar type: 670-925; fish, canned with edible bone: 190-400; greens: collard, kale, mustard, turnip: 220-259; milk: 118; soybean, and soyflours: 195-265.
19	Iron, mg	Egg yolk: 7.2; greens: collards, kale, mustard, spinach, turnip: 1.6-3.0; legumes, dry: 4.7-8.0; liver, all kinds: 6.6-18.0; wheat: 3.0-4.3.

/1/ Canned. /2/ Raw, fresh. /3/ Includes Atlantic mackerel, halibut, salmon, swordfish.

Allowances are designed for the maintenance of good nutrition of healthy persons normally vigorous and active, living in a temperate climate.[1]

	Group	Age yr	Weight kg (lb)	Height cm (in.)	Calories[2]	Protein[3] g	Vitamin A I. U.	Ascorbic Acid mg	Vitamin D[4] I. U.	Niacin[5] mg	Ribo-flavin[6] mg	Thia-mine[7] mg	Calcium g	Iron mg	Other Nutrients[8]
1	Men	25	65(143)	170(67)	3200	65	5000	75		16	1.6	1.6	0.8	12	+
2		45	65(143)	170(67)	2900	65	5000	75		15	1.6	1.5	0.8	12	+
3		65	65(143)	170(67)	2600	65	5000	75		13	1.6	1.3	0.8	12	+
4	Women	25	55(121)	157(62)	2300	55	5000	70		12	1.4	1.2	0.8	12	+
5		45	55(121)	157(62)	2100	55	5000	70		11	1.4	1.1	0.8		+
6		65	55(121)	157(62)	1800	55	5000	70		10	1.4	1.0	0.8	12	+
7	Pregnant (3rd trimester)				Add 400	80	6000	100	400	15	2.0	1.5	1.5	15	+
8	Lactating (850 ml daily)				Add 1000	100	8000	150	400	15	2.4	1.5	2.0	15	+
9	Infants[9]	1/12 to 3/12	6(13)	60(24)	kg x 120	kg x 3.5	1500	30	400	3	0.4	0.3	0.6	6	+
10		4/12 to 9/12	9(20)	70(28)	kg x 110	kg x 3.5	1500	30	400	4	0.7	0.4	0.8	6	+
11		10/12 to 1	10(22)	75(30)	kg x 100	kg x 100	1500	30	400	5	0.9	0.5	1.0	6	+
12	Children	1-3	12(27)	87(34)	1200	40	2000	35	400	6	1.0	0.6	1.0	7	+
13		4-6	18(40)	109(43)	1600	50	2500	50	400	8	1.2	0.8	1.0	8	+
14		7-9	27(59)	129(51)	2000	60	3500	60	400	10	1.5	1.0	1.0	10	+
15	Boys	10-12	35(78)	144(57)	2500	70	4500	75	400	13	1.8	1.3	1.2	12	+
16		13-15	49(108)	163(64)	3200	85	5000	90	400	16	2.1	1.6	1.4	15	+
17		16-20	63(139)	175(69)	3800	100	5000	100	400	19	2.5	1.9	1.4	15	+
18	Girls	10-12	36(79)	144(57)	2300	70	4500	75	400	12	1.8	1.2	1.2	12	+
19		13-15	49(108)	160(63)	2500	80	5000	80	400	13	2.0	1.3	1.3	15	+
20		16-20	54(120)	162(64)	2400	75	5000	80	400	12	1.9	1.2	1.3	15	+

/1/ Recommended by the Food and Nutrition Board, National Research Council, 1953. These allowances can be attained with a variety of common foods, which also provide nutrient requirements less well known. The allowances should cover individual variations among normal persons as they live in the U. S. A. subjected to ordinary environmental stresses. /2/ Allowance must be adjusted to meet specific needs; the proper allowance is that which over an extended period will maintain body weight or rate of growth at the "healthy" level. Adjustment for weight: For men and women differing from the standard body sizes of 65 and 55 kilograms (143 and 121 lb), the following formulas are applicable: Cal. for men = $152\ (W^{.073})$, Cal. for women = $123.4\ (W^{.073})$, where W = body weight in kilograms. For example, allowances for 25-year-old men weighing 50, 60, 70, and 80 kilograms, respectively, would be 2600, 3000, 3400, and 3700 Calories. Women of the same age and weighing 40, 50, 60, and 70 kilograms would receive, respectively, 1800, 2100, 2400, and 2700 Calories. These calorie allowances are based on proper, not actual, body weight for a given height. Adjustment for activity: For normally vigorous daily activity, make no correction; for sedentary life, reduce Calories by 22% for heavy work, add 20-25% for heaviest work add 50%. Adjustment for climate: A 5 per cent increase or decrease in calorie allowance for every 10° C difference (decrease or increase) in mean external temperature from the reference base of 10° C is proposed. For example, add 2% to Calories for extreme northern U. S. A.; subtract 5% for southern U. S. A. /3/ Allowance of 1 gram per day per kilogram of body weight should be adjusted according to body weight. /4/ Little evidence for need for supplemental Vitamin D by vigorous adults leading a normal life; however, for night workers and others whose habits shield them from sunlight, the ingestion of small amounts of the vitamin is desirable. /5/ Calorie-correlated; allowance is ten times that for thiamine. /6/ Computed from protein allowance, using a factor of 0.025. /7/ Calorie-correlated; allowance provides 0.5 milligrams for each 1000 Calories for adults, but the thiamine intake should not fall below 1 milligram daily. /8/ Carbohydrates and fats are essential for energy, but recommended allowances cannot be formulated as yet. Water: the standard is one ml per Calorie of food; much of this is in prepared foods. Sodium, potassium, and chlorine: indispensable dietary constituents. Potassium is widespread and does not need consideration as a dietary adjunct. The average normal adult intake of NaCl, 7-15 g, more than meets the normal requirement; additional quantities may be required with increased sweating. Phosphorus: allowance should equal that for calcium in diets of children and of women during latter part of pregnancy and lactation; for other adults allowance should be approximately 1½ times that for calcium. Copper: 1-2 mg daily for adults; for infants and children 0.05 mg/kg body weight. Iodine: 0.002-0.004 mg/kg body weight. There is presumptive evidence that cobalt, magnesium, manganese, molybdenum and zinc may be essential. Vitamin B_6 (pyridoxine group): approximate allowance is 1-2 mg daily. Vitamin B_{12} (cobalamin; cyanocobalamin): probably essential, but no requirement formulated. Folacin (folic acid group): less than 1 mg daily should be sufficient for any nutritional need. Vitamin K: requirement for maintance of normal blood prothrombin level is provided by the average diet. However, if supplementary K was not given mother antepartum (daily dose of 1 mg orally during last month of pregnancy), the newborn infant should receive a single dose of 1 mg. /9/ During the first month of life, allowances for many nutrients are dependent upon maturation of excretory and endocrine functions; therefore, no specific recommendations are given. From one month to one year the recommendations pertain to nutrients primarily from cow's milk.

165. DAILY DIETARY ALLOWANCES: MAN (CANADA, U. K., U. S. A.)[1]

Dietary standards of the three countries differ considerably in philosophy and objective. The Canadian standard represents "a nutritional floor beneath which maintenance of the health of the people cannot be assumed." The British standards "are believed to be sufficient to establish and maintain a good nutritional state in representative individuals of population groups." The American allowances[2] "represent not merely minimal needs of average persons, but nutrient levels selected to cover individual variations in a substantial majority of the population." All the allowances must be adjusted to the actual needs of the individual, particularly with respect to body weight, degree of activity, age and environment. The adult allowances are for normally healthy young adults living in temperate climate and engaged in work requiring moderate activity. Canadian standards for children neither combine allowances for girls and boys, nor place children in age groups, nor treat children (age 16-20) differently from adults; however, for comparisons with U. K. and U. S. A. standards, rough averages have been made to arrive at the values shown in this table.

	Group	Age yr	Weight kg	Calories[3]	Protein[4] g	Vit. A[5] I. U.	Vit. C[6] mg	Vit. D I. U.	Niacin mg	Ribo-flavin mg	Thia-mine mg	Calcium g	Iodine mg	Iron mg	Phos-phorus g
	Adult Male														
1	Can.		64	2900[7]	60	4600	30		8.5	1.4	0.9	0.65	0.15-0.30	6	0.65
2	U. K.		65	3000	82	5000	20		12	1.8	1.2	0.8	0.1	12	
3	U. S. A.	25	65	3200	65	5000	75		16	1.6	1.6	0.8	0.15-0.30	12	1.2
	Adult Female														
4	Can.		55	2400[7]	55	4000	30		7.5	1.1	0.8	0.55	0.15-0.30	12	0.55
5	U. K.		56	2500	69	5000	20		10	1.5	1.0	0.8	0.1	12	
6	U. S. A.	25	55	2300	55	5000	70		12	1.4	1.2	0.8	0.15-0.30	12	1.2
	Pregnancy														
7	Can.			2900	80	6000	30	400	9	1.3	1.0	1.55	0.15-0.30	15	1.55
8	U. K.			2750	96	6000	40	400-600	11	1.6	1.1	1.5	0.15	15	
9	U. S. A.			2700	80	6000	100	400	15	2.0	1.5	1.5	0.15-0.30	15	1.5
	Lactation														
10	Can.			3400	80	6000	30	400	10.5	1.6	1.1	1.55	0.15-0.30	15	1.55
11	U. K.			3000	111	8000	50	800	14	2.1	1.4	2.0	0.15	15	
12	U. S. A.			3300	100	8000	150	400	15	2.5	1.5	2.0	0.15-0.30	15	2.0
	Children														
	1/12-9 yr														
13	U. K.	<1	8	800	28	1500	10	800	3	0.5	0.3	1		6	
14	U. S. A.	4/12-9/12	8	kg x 110	kg x 3.5	1500	30	400	4	0.7	0.4	0.8	kg x 0.003	6	0.8
15	Can.	1-3	12	1250	37	860	30	400-800	3.7	0.6	0.4	1		6	
16	U. K.	1-3	12	1300	46	1500	15	400	5	0.8	0.5	1	0.15	7	
17	U. S. A.	1-3	12	1200	40	2000	35	400	6	1.0	0.6	1.0	kg x 0.003	7	1.0
18	Can.	4-6	19	1625	38	1400	30	400	5	0.8	0.5	1		6	
19	U. K.	4-6	18	1600	56	1500	15	400	6	1	0.6	1	0.15	8	
20	U. S. A.	4-6	18	1600	50	2500	50	400	8	1.2	0.8	1.0	kg x 0.003	8	1.0
21	Can.	7-9	26	2025	49	1900	30	400	6	1.1	0.6	1		6	
22	U. K.	7-9	27	1950	68	1500	20	400	8	1.2	0.8	1	0.15	10	
23	U. S. A.	7-9	27	2000	60	3500	60	400	10	1.5	1.0	1.0	kg x 0.003	10	1.0
	10-20 yr		♂♀	♂ ♀	♂ ♀	♂ ♀	♂ ♀	♂♀	♂ ♀	♂ ♀	♂ ♀	♂ ♀	♂♀	♂	♂ ♀
24	Can.	10-12	34|37	2400|2500	60 | 62.5	2400|2700	30 | 30	400	7.2|7.2	1.5|1.5	0.7|0.7	1	1	6	
25	U. K.	10-12	35|35	2450|2450	86 | 86	1500|1500	25 | 25	400	10 |10	1.5|1.5	1 | 1	1.2|1.2	0.15	12	
26	U. S. A.	10-12	35|36	2500|2300	70 | 70	4500|4500	75 | 75	400	13 |12	1.8|1.8	1.3|1.2	1.2|1.2	kg x 0.003	12	1.2|1.2
27	Can.	13-15	49|49	2950|2500	75 | 75	3500|3500	30 | 30	400	9 |7.5	1.5|1.2	0.9|0.7	1.5|1.5		12	
28	U. K.	13-15	49|49	3150|2750	110|96	1500|1500	30 | 30	400	13 |11	1.9|1.6	1.3|1.1	1.4|1.3	0.15	15	
29	U. S. A.	13-15	49|49	3200|2500	85 | 80	5000|5000	90 | 80	400	16 |13	2.1|2.0	1.6|1.3	1.4|1.3	kg x 0.003	15	1.4|1.3
30	Can.	16-20	60|53	3500|2400	60 | 55	4300|1800	30 | 30	400	8.5|7.5	1.7|1.1	1.1|0.7	1.5|1.5		12	
31	U. K.	16-20	63|54	3400|2500	119|88	2500|2500	30 | 30	400	14 |10	2.1|1.5	1.4|1.0	1.4|1.0	0.15	15	
32	U. S. A.	16-20	63|54	3800|2400	100|75	5000|5000	100|80	400	19 |12	2.5|1.9	1.9|1.2	1.4|1.3	kg x 0.003	15	1.4|1.3

/1/ Canadian values were adopted from "Nutrition," a bulletin of the Canadian Council on Nutrition, Ottawa: King's Printer and Controller of Stationery, 1950, and from the Canadian Bulletin on Nutrition 3:No. 2, 1953. Values for U. K. were adapted from "Report of the Committee on Nutrition," London: British Medical Association, 1950, and "Report of the National Food Survey Committee," London: Her Majesty's Stationery Office, 1952. Values for U. S. A. were derived from "Recommended Dietary Allowances." Food and Nutrition Board, Washington: National Research Council, 1953. /2/ For further details see Table 164. /3/ Allowance must be adjusted for variations in body weight, activity, and climate. See Footnote 2, Table 164. /4/ Allowance should be adjusted for variations in body weight; the general standard is one gram of protein per kilogram of body weight. /5/ Canadian allowance is expressed as I. U. of carotene, one I. U. is equivalent to 0.0006 mg β-carotene. The British and American allowances are expressed as I. U. in a diet containing both carotene and preformed A (one I. U. preformed A alcohol = 0.0003 mg). /6/ Ascorbic acid. /7/ The work allowance for "moderate activity" included in the total calorie allowance is 800 Calories for men and 500 Calories for women. Deducting these figures from the total allowance will give the maintenance requirement.

Values are for maintenance and normally vigorous activity of male, adult animals, and are per kg body weight per day, unless otherwise indicated.

Required (R); Not Required (¥)

	Nutrients	Man U. S. A.[1] 25 yr; 65 kg	Beef Cattle[2] 800 kg	Dairy Cattle[2] 900 kg	Dog[3]	Fox[3] 5.7 kg	Hamster[4] 0.025 kg	Horse[2] 635 kg	Monkey, Rhesus	Mouse[4] 0.025 kg	Rat, White 0.30 kg	Sheep[2] 79 kg	Swine[3] 227 kg	Chicken[1,5] 1.82 kg	Fish, Rainbow Trout
1	Water, ml	49	47	R	R	R	R	R	R	180	R	70	R	110	
2	Calories[6], metabolizable	49	32	28	75	122	645	43	160	500	115	51	45	150	
3	Total food or feed, g	10.8	15	14	20-35	25	150	19	40	120	50	31	15	51	50-60
4	Residue, g						4.8		7.2		¥			¥	
5	Protein[7], g	1	0.8	0.7	3-4	5	32	0.8	28.4	40	R	1.1	2.1	7.7	7-8
6	Carbohydrate, g	8.5				R	105	9.1		70	¥	12		25	1-5
7	Fat, g	1.1-1.4			1.3		11.2	0.4		20	¥	0.33	R	1.2	1-3
8	Vitamin A, I.U.[8]	77	150	150	100	50	1800	150	60	1000	17	150	135	215	R
9	Ascorbic acid, mg	1.1			¥		¥		4	¥	¥		¥		20-40
10	Biotin, μg	R			¥(?)		20	R	8	30	10			(?)	15-26
11	Choline, mg				33		640		40	200	40			56	4-8
12	Cobalamin, μg	R(?)			0.55		¥(?)		(?)	4	R(?)	1.7	R		R(?)
13	Vitamin D, I.U.[9]	R		R	6.6	R	270	6.6	12.8	100	¥	8	3	25.6[10]	¥(?)
14	Vitamin E, mg		R	R			4.0		2.0	5	1.2	0.3	R		R(?)
15	Folic acid group, μg	R(?)			8	5	320	R	80	500	¥(?)			15	100-200
16	Inositol, mg				¥		400		40	¥(?)	¥				20-40
17	Vitamin K, μg	R			¥		4800		40	1000	¥				R(?)
18	Niacin, mg	0.25			0.24	0.26	9.0	0.1	1.0	5	¥		0.17		3-4
19	Pantothenic acid, mg	R			0.05	0.20	1.6	R(?)	0.8	10	0.36		0.15	0.28	1-1.3
20	Para-aminobenzoic acid, mg				¥		160		12(?)	¥	¥				R(?)
21	Pyridoxine group, μg	15-31			25	30	1900	R	140	1000	40			150	200-300
22	Riboflavin, μg	25			45	50	2600	R	140	2000	100		40	130	400-700
23	Thiamine, μg	25			18	30	1300	R	140	1000	50		17		100-200
24	Calcium, mg	12	22	18	250	160		28	155	900	160-200	45	90	1150	R
25	Chlorine, mg	93	30	R	225	R		R	230	800	20	150	45	160	
26	Cobalt, μg	R(?)	2000	R	6			(?)	19	400	¥	100			
27	Copper, μg	18	R	R	165			(?)	480	700	1000	2000	R		
28	Fluorine, mg								0.04	0.6	¥(?)				
29	Iodine, μg	2-4	R	R	33			R	600	1300	8		<4	20	R
30	Iron, mg	0.18	R	R	1.3				5	30	5	R	R		
31	Magnesium, mg	R(?)	R	R	11			R	10	60	5		R		
32	Manganese, mg	R(?)	0.3	0.3	0.11				1.6	5	2		R	1.7	
33	Molybdenum	R(?)													
34	Phosphorus, mg	18	22	18	220	160		31	170	900	140-180	40	60	385	
35	Potassium, mg	R	R	R	220				135	600	60		55-110		
36	Sodium, mg	60	20	R	150	R			130	500	200	100	30	100	
37	Sulfur, mg	R	R	R				R	14		g[11]				
38	Zinc, mg	R(?)	R		0.11				0.9	0.3	R		R		

/1/ Values are daily dietary allowances calculated from those recommended by the Food and Nutrition Board, National Research Council, 1953. /2/ Values are daily nutrient allowances calculated from those recommended by the Committee on Animal Nutrition, Agricultural Board, National Research Council, 1949-50; a few values have been changed in accordance with revisions recommended by the Committee. /3/ Values are daily nutrient requirements calculated from those recommended by the Committee on Animal Nutrition, 1953-54; a few values have been changed in accordance with revisions recommended by the Committee. /4/ Young animal, sex not specified. /5/ Single comb white leghorn, laying. /6/ Kilocalories. /7/ Digestible. /8/ One I.U. = 0.0006 mg β-carotene. /9/ One I.U. = 0.025 μg calciferol. /10/ International Chick Units; one unit = 0.025 μg D_3 (7-dehydrocholesterol). /11/ Except as sulfur-containing amino acids.

167. VITAMINS, SUMMARY OF ESTIMATED DAILY ALLOWANCES: VERTEBRATES

Values are per kg body weight per day, unless otherwise indicated.

	Animal	Condition[1]	Required (R) or Not Required (d). Vitamin A, I. U.[2]	Ascorbic Acid mg	Biotin µg	Choline mg	Cobalamin µg	Vitamin D, I. U.[3]	Vitamin E mg	Folic Acid Group µg	Inositol mg	Vitamin K µg	Niacin mg	Pantothenic Acid mg	Para-amino-benzoic Acid mg	Pyridoxin µg	Riboflavin µg	Thiamine µg
1	Cat[4]	Growth ♂♀	135					19					2.3				320	50
2		Maintenance ♂♀	85					12					1.4				190	30
3	Cattle, beef	Growth ♂♀	215		R[5]	R	R[5]	7	R			R(?)		R[5]		R[5]	275	R[5]
4		Maintenance ♂♀	150						R									
5		Pregnancy	215						R									
6		Lactation	1000						R									
7	Cattle, dairy	Growth ♂♀	150		R[5]	R	R[5]	6, 6	R			R(?)	R	R[5]		R[5]	305	R[5]
8		Maintenance ♂♀	150					R	R									
9		Pregnancy	260					R	R									
10		Lactation	260					R	R									
11	Dog	Growth ♂♀	200	R		55	1.1	21		15	R	R	0.4	0.1	R	55	90	33
12		Maintenance ♂♀	100	R (?)	R(?)	.33	0.55	6.6		8	R	R	0.24	0.05	R	25	45	18
13	Fox	Growth ♂	135					R		14			0.74	0.56		80	140	80
14		♀	100					R		12			0.63	0.50		70	120	70
15		Maintenance ♂♀	50					R		5			0.26	0.20		30	50	30
16	Guinea pig	Growth ♂♀	R	100-200[6]	R(?)	1000-1500[6]		R(?)	60-120[6]	3000-5000[6]	R(?)	2000	10-20[6]	15-20[6]	R	R	3000[6]	6000-8000[6]
17		Reproduction		100-200[6]	R(?)						R(?)	R						
18	Hamster	Growth ♂♀	1800	R	20	640	R(?)	270	4, 0	320	400	4800	8.0	1.6	160	1900	2600	1300
19	Horse	Growth ♂♀	185		R			6.6		R			0.1	R(?)		R	R	R
20		Maintenance ♂♀	150		R			6.6		R			0.1	R(?)		R	R	R
21		Pregnancy	215		R			6.6		R			0.13	R(?)		R	R	R
22		Lactation	215		R			6.6		R			0.13	R(?)		R	R	R
23	Mink	Growth ♂	165					R		20			0.98	0.80		100	200	100
24		♀	180					R		22			1.11	0.89		130	220	130
25		Maintenance ♂	135					R		19			0.78	0.63		90	150	90
26		♀	165					R		21			1.0	0.79		120	210	120
27	Monkey	Growth and maintenance ♂♀	60	4	8	40	(?)	13	2	80	40	40	1	0.8	12(?)	140	140	140
28	Mouse	Growth ♂♀	1000	R	30	200	4	100	5	500	R(?)	1000	5	10	R	1000	2000	1000
29	Rabbit	Growth ♂♀		R					0.32				225[6](?)				R	
30		Maintenance ♂♀		R									55				R	
31	Rat, cotton	Growth ♂♀	1500	R	20	160		200		320	160		4.0	3.2	48	400	480	400
32	Rat, white	Growth ♂♀	17	R	10	80	0.4	R	3.0(?)	8.0	R	R(?)	R(?)	1.0	R	300	300	200
33		Maintenance ♂♀	17	R	10	40	R(?)	R	1.2	R(?)	R	R	0.36	R	40	100	50	
34		Pregnancy	R	R	10	50	R(?)	R	1.5	R(?)	R	R(?)	R(?)	0.45	R	90	40	50
35		Lactation	R	R	12	60	R	R	1.5	R(?)	R	R(?)	R(?)	0.45	R	70	20	50
36	Sheep	Growth ♂♀	215					8	0.3					R[5]		R[5]	R[5]	R[5]
37		Maintenance ♂♀	150				1.7	8	0.3									
38		Pregnancy	215				1.7	8	0.3									
39		Lactation	235				1.7	8	0.3									
40	Swine	Growth ♂♀	75	R		R	0.5	9.2		R			0.5	0.45		<110	100	50
41		Breeding ♂	135	R			R	3	R				0.17	0.15			40	17
42		Lactation	250	R			R	5.6	R				0.31	0.27			70	30
43	Chicken[7]	Growth ♂♀	350	R	12	175	1.2	26	2.6	70		52	3.5	1.23		380	380	240
44		Laying	265	R	8	56		30		15				0.28		170	130	
45		Breeding ♀	265	R	7	56	0.2	30		21			0.45	0.55		170	230	
46	Duck	Growth ♂♀						220[6]					55[6]	110		35	4[6]	
47	Turkey[8]	Growth ♂♀	400	R		125		68		70		100	3.7	0.83		260	280	
48		Breeding ♀	165	R				28		200				0.42			110	
49	Trout[9]	Maintenance	R	20-40	15-26	4-8	R(?)	R(?)	R(?)	100-200	20-40	R(?)	3-4	1-1.3	R(?)	200-300	400-700	100-200

/1/ Values for growth are for very young animals (i.e., about 1/4 grown). Maintenance values are for adults. /2/ One I.U. = 0.0006 mg β-carotene. /3/ One I.U. = 0.025 µg calciferol. Requirements for poultry expressed in International Chick Units. /4/ Diet of raw, unprocessed feed. Values are rough approximations, and may be inadequate for proper maintenance. /5/ Required only until vitamin is synthesized in the rumen. /6/ Per kilogram of feed. /7/ Single comb white leghorn. /8/ Broad-breasted bronze turkey. /9/ Rainbow trout.

168. DAILY NUTRIENT ALLOWANCES: BEEF AND DAIRY CATTLE

Data are from Reports no. III and IV, Committee on Animal Nutrition, National Research Council, 1950. Based on air-dry feed containing 90% dry matter. Allowances are probably higher than minimum requirements. Bf = beef cattle; Dr = dairy cattle.

	Specifications	Heifers and Steers						Bulls		Cows					
		Growth						Maintenance[1]		Maintenance				Lactating	
		Bf	Dr[2]	Bf	Dr[2]	Bf	Dr[2]	Bf	Dr	Bf	Dr	Bf[3]	Dr	Bf[4]	Dr[5]
		400		600		800	1000	1200		1000	1200	800		1200	1000
1	Weight, lb														
2	Expected dailygain,lb	1.6	1.8	1.4	1.4	1.2	1.0	1.3	1.4			1.5			
3	Total feed, lb	12	11	16	15	19	21	22	22	18	26	27	22	14	18	18	28
4	Digestible protein, lb	0.9	0.8	0.9	0.85	0.9	0.9	0.95	1.4	1.0	1.4	1.45	1.0	0.5	0.8	0.7	1.4
5	TDN[6], lb	7.0	6.5	8.5	8.5	9.5	10.0	10.5	11.0	13.0	10.3	14.0	15.6	11.0	6.8	9.0	9.2
6	Calcium[7], g	20	20	18	18	16	16	15	15	21	12	18	20	22	8	16	12
7	Phosphorus[8], g	15	15	15	15	15	15	15	15	18	12	18	20	18	8	15	12
8	Carotene[9], mg	24	24	36	36	48	48	60	60	72	72	108	120	48	48	72	72
9	Vitamin D[9], I.U.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

/1/ Moderate activity; breeding. /2/ Large breeds. /3/ Pregnant. /4/ Nursing calves, 3-4 months after parturition. /5/ Assuming 40 lb milk daily with 4% fat. /6/ Total digestible nutrients. /7/ Fe, Cu, I, Mg, Mn, Co, K, S, Na and Cl are probably essential, but quantitative requirements have not been defined. /8/ 0.0006 mg β-carotene = one I. U. /9/ Usually obtained in sufficient quantities from sunlight or sun-cured roughages. Young animals should be given 400 I. U. per 100 lb body weight.

169. DAILY NUTRIENT REQUIREMENTS: SWINE

Data are from Report no. II, Committee on Animal Nutrition, National Research Council, 1950.

	Specifications	Market Stock						Pregnant ♀ and Breeding ♂		Lactating ♀	
								Young	Adult	Gilts	Adult
1	Weight, lb	25	50	100	150	200	250	300	500	350	450
2	Expected daily gain, lb	0.8	1.2	1.6	1.8	1.8	1.8	0.75	0.5		
3	Total feed[1], lb	2.0	3.2	5.3	6.8	7.5	8.0	6.0	7.5	11.0	12.5
4	TDN[2], lb	1.6[3]	2.4	4.0	5.1	5.6	6.2	4.5	5.6	8.3	9.4
5	Crude protein, lb	0.36	0.51	0.74	0.88	0.9	1.0	0.90	1.05	1.65	1.75
6	Calcium[4], g	7.3	9.4	15.6	17.0	18.7	20.7	16.3	28.4	30.0	36.0
7	Phosphorus[5], g	5.4	6.5	10.8	10.2	11.2	12.4	10.9	13.6	20.0	22.7
8	Sodium, as NaCl, g	4.5	7.3	12.0	15.4	17.0	18.8	13.6	17.0	25.0	28.4
9	Vitamin B_{12}[6], μg	20.0	16.0	26.5							
10	Carotene[6], mg	0.5	1.0	2.0	3.0	4.0	5.0	15.0	18.7	27.5	31.2
11	Choline, mg	800.0									
12	Vitamin D, I.U.	180.0	288.0	497.0	612.0	695.0	747.0	540.0	675.0	990.0	1125.0
13	Niacin, mg	16.0	19.2	26.5	34.0	37.5	41.5	30.0	37.5	55.0	62.5
14	Pantothenic acid, mg	10.0	16.0	23.8	30.6	33.8	37.4	27.0	33.8	49.5	56.2
15	Pyridoxine, mg	1.2	1.9								
16	Riboflavin, mg	2.4	3.2	5.3	6.8	7.5	8.3	7.2	9.0	13.2	15.0
17	Thiamine, mg	1.0	1.6	2.6	3.4	3.8	4.2	3.0	3.8	5.5	6.2

/1/ Air-dried. /2/ Total digestible nutrients (75% TDN). /3/ For young pigs a high energy diet (80% TDN) is recommended. /4/ Fe, Cu, I, Mg, Co, K and Zn are probably essential, but quantitative requirements have not been defined. /5/ Cobalamin; cyanocobalamin. /6/ 0.0006 mg β-carotene = one I. U.

170. DAILY NUTRIENT REQUIREMENTS: CHICKEN

Data are from Report no. 1, Committee on Animal Nutrition, National Research Council, 1954. Wh = single-comb white leghorn or similar breeds; Hb = heavy breeds.

	Specifications	Growth										Laying[1]		Breeding[1]	
		Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb
	Age, wk	3-4	3	5-6	5	7.5-8.5	?	10-11	8-9	11-14	10-11	14-18	12	36-52	?
2	Weight, lb	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	3.0	3.0	4.5	4.0	5.5
3	Total feed, lb	0.66	0.96	2.09	2.10	3.17	3.13	3.16	3.18	3.17	3.24	3.0	3.0	3.0	3.0
4	Crude protein, lb	0.013	0.012	0.019	0.021	0.019	0.024	0.025	0.029	0.025	0.028	0.038	0.027	0.031	0.036
5	Calcium, g	0.30	0.28	1.0	0.44	0.68	0.53	0.59	0.71	0.82	0.80	1.09	0.76	0.87	2.46
6	Iodine, mg	0.033	0.031	0.049	0.051	0.023	0.065	0.031	0.036	0.035	0.048	0.034	0.038	0.048	0.055
7	Magnesium, mg	14.7	13.6	21.3	22.7	?	28.8	?	?	?	?	?	?	?	?
8	Manganese, mg	1.68	1.55	2.43	2.58	?	3.28	?	?	?	?	?	?	?	?
9	Phosphorus, g	0.18	0.16	0.26	0.28	0.32	0.35	0.43	0.493	0.48	0.654	0.46	0.523	0.66	0.75
10	Potassium, mg	61	56	88	94	85	119	113	131	127	174	122	139	?	?
11	Vitamin A, I. U.[4]	80.0	74.0	116.0	124.0	140.0	157.0	187.0	217.0	210.0	288.0	202.0	230.0	482.0	552.0
12	Biotin, μg	2.7	2.5	3.9	4.1	?	5.2	?	?	?	?	?	?	?	?
13	Choline, mg	40.0	37.0	58.0	62.0	?	78.6	?	?	?	?	?	?	?	?
14	Vitamin D, I.C.U.[5]	6.0	5.6	8.7	9.3	10.5	11.8	14.0	16.3	15.8	21.6	15.1	17.3	54.2	62.1
15	Folacin, μg	16.8	15.5	24.3	25.8	?	33	?	?	?	?	?	?	27	30
16	Niacin, mg	0.80	0.74	1.16	1.24	?	1.57	?	?	?	?	?	?	?	?
17	Pantothenic acid, mg	0.28	0.26	0.41	0.43	0.49	0.55	0.66	0.76	0.74	1.01	0.71	0.81	0.51	0.58
18	Pyridoxine, mg	0.087	0.081	0.126	0.134	?	0.170	?	?	?	?	?	?	0.31	0.36
19	Riboflavin, mg	0.087	0.081	0.126	0.134	0.094	0.170	0.125	0.145	0.140	0.192	0.134	0.154	0.241	0.276
20	Thiamine, mg	0.054	0.050	0.078	0.082	?	0.105	?	?	?	?	?	?	?	?

/1/ 60% production. /2/ Value for maintenance is 0.156. /3/ Value for maintenance is 0.192. /4/ One I. U. = 0.3 μg A alcohol, or 0.6 μg β-carotene = one U. S. P. unit. /5/ Vitamin D_3 (7-dehydrocholesterol). 0.025 μg crystalline D_3 = one I. C. U. (International Chick Unit). Chickens and turkeys utilize D_2 from irradiated ergosterol) poorly.

171. AMINO ACID REQUIREMENTS, AND COMPOSITION IN VARIOUS FOODS

Ranges, in parentheses, are estimate "c" of the 95% range (cf Introduction).

Amino Acid	Essential (R); utilized (U). Requirements[1]						Composition							
	Man[2], Adult 70 kg	Rat[3], Adult 0.15 kg	Chicken[4], Young 0.25 kg	Dog[5], Adult 7 kg	Swine[6], Young 45 kg	Beef Muscle[7]	Casein[7]	Egg Albumin[7]	Egg Powder[7]	Peanut Flour[7]	Wheat Gluten[7]	Milk, Mature: Man	Milk, Mature: Cow	Milk, Mature: Sow
	grams per animal per day					grams per 100 grams protein						mg per 100 ml milk		
1 Alanine	U	U										35	75	
2 Arginine	U	U	R 0.47	R 0.49	R 6.1	6.42	3.72	5.31	5.43	7.41	3.30	51(28-67)	124(90-173)	316
3 Aspartic acid	U	U				9.33	6.93	9.76	9.40	8.52	3.38	116	166	
4 Citrulline	U													
5 Cystine[8]	U	U	R ? 0.13			1.34	0.38	2.64	2.00	0.95	2.12	29(20-41)	29(23-34)	
6 Glutamic acid	U	U				14.61	21.31	11.45	10.96	12.03	31.36	230 *	680	
7 Glycine	U	R 0.39				5.62	1.89	3.34	3.45	3.53	2.97	0	11	
8 Histidine	U	R 0.005	R 0.06	R 0.17	R 11.7	3.24	2.89	2.15	1.84	1.46	1.78	23(12-38)	80(51-130)	120
9 Hydroxyproline	U													
10 Isoleucine	R 0.70	R 0.03	R 0.23	R 0.56	R 16.4	5.16	4.63	5.73	5.39	2.72	4.07	86(46-114)	212(159-290)	234
11 Leucine	R 1.08	R 0.02	R 0.56	R 0.77	R 23.4	7.79	9.53	7.79	7.87	4.65	6.45	161(72-228)	356(240-600)	643
12 Lysine	R 0.80	R 0.009	R 0.35	R 0.42	R 29.2	8.58	7.71	6.39	5.35	2.29	1.81	79(50-111)	257(184-382)	408
13 Methionine	R 1.08	R 0.01	R 0.17	R 0.49	R 17.6	2.70	3.09	3.69	2.81	0.55	1.49	23(6-36)	87(50-140)	75
14 Phenylalanine	R 1.08	R 0.007	R 0.35	R 0.46	R 26.1	3.88	5.15	5.27	4.93	3.23	4.52	64(30-77)	171(111-228)	192
15 Proline	U					5.13	12.72	3.81	3.91	3.26	12.66	80	250	
16 Serine	U											69	160	
17 Threonine	R 0.49	R 0.01	R 0.23	R 0.38	R 11.7	4.44	4.28	4.33	4.31	1.83	2.51	62(40-76)	152(115-220)	750
18 Tryptophan	R 0.24	R 0.005	R 0.08	R 0.10	R 5.8	1.01	0.91	1.02	0.99	0.51	0.69	22(13-31)	50(36-80)	200
19 Tyrosine[9]	U		R ? 0.27			2.95	4.90	2.96	3.09	1.90	2.50	62(47-78)	190(158-251)	
20 Valine	R 0.80	R 0.02	R 0.31	R 0.59	R 11.7	5.13	7.01	6.62	6.10	3.00	3.81	90(48-133)	228(171-321)	1150

/1/ Values are essentially minimum requirements; for man they probably should be doubled to represent a "safe" allowance for normal, healthy adults, and this may be true for the other species listed. /2/ Values for man represent the L-forms of the amino acids, except glycine. /3/ White rat. /4/ New Hampshire. /5/ Cocker spaniel. The amino acids for which values are given probably are required, although the data available do not show this clearly. /6/ Synthetic diet with amino acids and diammonium citrate as nitrogen sources. /7/ Ash and moisture-free basis for partially purified proteins. /8/ Will replace about 1/2 of the methionine requirement. /9/ Will replace a portion of the phenylalanine requirement.

172. AMINO ACID REQUIREMENTS: INSECTS, BACTERIA

Required (R); not required (R).

Amino Acid	Insects[1]							Bacteria[2]										
	Cockroach, Germans; nymph[3]	Beetle, carpet; larva[4]	Beetle, confused flour; larva[4]	Fly, fruit, vinegar; larva[4]	Mosquito, yellow fever; larva[4]	Parasite, spruce budworm; larva[4]	Aerobacter aerogenes	Bacillus anthracis	B. lichenformis	B. megatherium	B. subtilis	Brucella suis	Erwinia amylovora	Escherichia coli	Lactobacillus casei	Leuconostoc mesenteroides	Pasteurella tularensis	Salmonella typhosa	Serratia marcescens	Shigella paradi
1 Alanine	R[9]	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
2 Arginine	R[9]	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
3 Aspartic acid	R[9]	R	R	R	R	R									R					
4 Citrulline							R		R	R	R	R	R	R	R	R			R	R
5 Cystine	R[9]	R	R	R	R ?	R	R		R	R	R	R	R	R	R	R	R		R	R
6 Glutamic acid	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
7 Glycine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
8 Histidine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
9 Hydroxyproline	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
10 Isoleucine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
11 Leucine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
12 Lysine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R ?			R	R
13 Methionine	R[9]	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
14 Norleucine		R					R		R	R	R	R	R	R	R	R			R	R
15 Phenylalanine	R	R	R	R	R ?	R														
16 Proline	R[9,10]	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
17 Serine	R[9,10]	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
18 Threonine	R	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
19 Tryptophan	R ?	R	R	R	R	R	R		R	R	R	R	R	R	R	R		R	R	R
20 Tyrosine	R	R	R	R	R ?	R	R		R	R	R	R	R	R	R	R			R	R
21 Valine	R[9]	R	R	R		R	R		R	R	R	R	R	R	R	R			R	R
22 Other am. acids[11]								R									R	R		R
23 Other N source[12]							R		R	R	R	R	R	R					R	R

/1/ Diets containing all amino acids produce slightly better growth than mixtures of "required" acids alone. L-forms are biologically active, but the D-forms may be active for some species. See Table 173 for amino acid requirements of some additional species. /2/ There is wide variation in requirements among strains of a given species. /3/ Blattella germanica (L.). /4/ Attagenus (sp). /5/ Tribolium confusum Duv. /6/ Drosophila melanogaster Meig. /7/ Aedes aegypti(L.). /8/ Pseudosarcophaga affinis (Fall.). /9/ Synthesized under aseptic conditions but at a rate insufficient for normal growth and/or development. /10/ Required by males only. /11/ Unspecified. /12/ NH_3, etc.

All insect tissues, and diets, contain nitrogen, carbon, oxygen and hydrogen. In addition, phosphorus, sulfur, iron, copper, magnesium, manganese, potassium, calcium and chlorine are probably universally required by insects. A number of other minerals, some only in traces, are consumed and found in the composition of the insect.

R = required; R = not required; U = utilized; U = not utilized; u = poorly utilized.

	Nutrient	Value
	Bee, honey, adult (Apis mellifera)	
1	Carbohydrates	U
2	Arabinose	u
3	Cellobiose	u
4	Dextrin	U
5	Fructose	U
6	Galactose	u
7	Glucose	U
8	Inulin	U
9	Lactose	R
10	Maltose	U
11	Mannitol	U
12	Mannose	U
13	Raffinose	U(?)
14	Sorbitol	U
15	Sorbose	U
16	Starch	u
17	Sucrose	U
18	Xylose	U(?)
	Beetle, carpet, larva (Attagenus sp)	
19	Casein	U
20	Protein, total	6-12%[1]
21	Alanine	R
22	Arginine	R
23	Aspartic acid	R
24	Cystine	R
25	Glutamic acid	R
26	Glycine	R
27	Histidine	R
28	Hydroxyproline	R
29	Isoleucine	R
30	Leucine	R
31	Lysine	R
32	Methionine	R
33	Norleucine	R
34	Phenylalanine	R
35	Proline	R
36	Serine	R
37	Threonine	R
38	Tryptophan	R
39	Tyrosine	R
40	Valine	R
41	Carbohydrates	R
42	Fatty acids	R
43	Sterols, derivatives	R
44	Cholestanol	U
45	Cholesterol	U
46	Ergosterol	u
47	Biotin	R
48	Choline	R
49	Folic acid group	R
50	Inositol	R
51	Niacin	R
52	Pantothenic acid	R
53	Para-aminobenoic acid	R
54	Pyridoxine group	R
55	Riboflavin	R
56	Thiamine	R
	Beetle, cigarette, larva (Lasioderma serricorne)	
57	Casein	U
58	Lactalbumin	U
59	Protein, total	45%[1]
60	Carbohydrates	U-R
61	Glucose	U
62	Starch	U
63	Sucrose	u(?)
64	Lipids, general	U
65	Fatty acids	R
66	Sterols, derivatives	R
67	Calciferol	U
68	Cholestanol	u
69	Cholesterol	U
70	Ergosterol	U
71	Sitosterol	U
72	Zymosterol	U
73	Biotin	R(?)
74	Choline	R(?)
75	Folic acid group	R
76	Inositol	R
77	Niacin	R
78	Pantothenic acid	R(?)
79	Para-aminobenoic acid	R(?)
	Beetle, cigarette, larva (Lasioderma serricorne) (concluded)	
80	Pyridoxine group	U(?)
81	Riboflavin	R
82	Thiamine	R
	Beetle, confused flour-, larva (Tribolium confusum)	
83	Casein	U
84	Gelatin	U
85	Lactalbumin	U
86	Zein	U
87	Protein, total	15-45%[1]
88	Alanine	R
89	Arginine	R
90	Aspartic acid	R
91	Cystine	R
92	Glutamic acid	R
93	Glycine	R
94	Histidine	R
95	Hydroxyproline	R
96	Isoleucine	R
97	Leucine	R
98	Lysine	R
99	Methionine	R
100	Phenylalanine	R
101	Proline	U
102	Serine	R
103	Threonine	R
104	Tryptophan	R
105	Tyrosine	R
106	Valine	R
107	Carbohydrates	R(?)
108	Arabinose	U
109	Cellobiose	U(?)
110	Dextrin	U(?)
111	Lactose	U
112	Galactose	U
113	Glucose	U
114	Inulin	U(?)
115	Lactose	U
116	Maltose	U
117	Mannitol	U
118	Mannose	U
119	Raffinose	U
120	Sorbitol	U
121	Sorbose	U
122	Sucrose	U
123	Xylose	U
124	Lipids, general	U
125	Fatty acids	R
126	Sterols, derivatives	R
127	Calciferol	U
128	Cholestanol	u(?)
129	Cholesterol	U
130	Ergosterol	U
131	Sitosterol	U
132	Zymosterol	U
133	Biotin	R
134	Choline	R
135	Folic acid group	R
136	Inositol	R
137	Niacin	U
138	Pantothenic acid	R
139	Para-aminobenoic acid	R
140	Pyridoxine group	R
141	Riboflavin	R
142	Thiamine	R
	Beetle, drug-store, larva[2] (Stegobium paniceum)	
143	Casein	U
144	Protein, total	45%[1]
145	Carbohydrates	50%[3]
146	Arabinose	U
147	Fructose	U
148	Galactose	U
149	Glucose	U
150	Inulin	U
151	Lactose	U
152	Maltose	U
153	Mannitol	U
154	Mannose	U
155	Raffinose	U
156	Sorbitol	U
	Beetle, drug-store, larva[2] (Stegobium paniceum) (concluded)	
157	Sorbose	U
158	Starch	U
159	Sucrose	U
160	Xylose	U
161	Lipids, general	U
162	Fatty acids	R
163	Sterols, derivatives	R
164	Calciferol	U
165	Cholestanol	U(?)
166	Cholesterol	U
167	Ergosterol	U
168	Sitosterol	U
169	Arginine	R
170	Biotin	R
171	Choline	R(?)
172	Folic acid group	R
173	Inositol	R(?)
174	Niacin	R
175	Pantothenic acid	R
176	Para-aminobenzoic acid	R
177	Pyridoxine group	U
178	Riboflavin	R
179	Thiamine	R
	Beetle, drug-store, adult (Stegobium paniceum)	
180	Biotin	R(?)
181	Choline	R(?)
182	Folic acid group	R(?)
183	Inositol	R
184	Niacin	R
185	Pantothenic acid	R
186	Para-aminobenoic acid	R
187	Pyridoxine group	R
188	Riboflavin	R
189	Thiamine	R
	Beetle, saw-toothed grain-, larva (Oryzaephilus surinamensis)	
190	Gelatin	U
191	Protein, total	45%[1]
192	Carbohydrates	U
193	Arabinose	U
194	Dextrin	U
195	Fructose	U
196	Galactose	U
197	Glucose	U
198	Inulin	U
199	Lactose	U
200	Maltose	U
201	Mannitol	U
202	Mannose	u
203	Raffinose	U
204	Sorbitol	U
205	Sorbose	U
206	Starch	U
207	Sucrose	U
208	Xylose	U
209	Lipids, general	U
210	Fatty acids	R
211	Sterols, derivatives	R
212	Calciferol	U(?)
213	Cholestanol	U
214	Cholesterol	U
215	Ergosterol	U
216	Sitosterol	U
217	Zymosterol	U
218	Biotin	U
219	Choline	U
220	Inositol	U
221	Niacin	R
222	Pantothenic acid	R
223	Para-aminobenzoic acid	U
224	Pyridoxine group	U
225	Riboflavin	R
226	Thiamine	U
	Beetle, spider, larva (Pitnus tectus)	
227	Casein	U
228	Protein, total	45%[1]
229	Carbohydrates	U-R
230	Glucose	u
231	Starch	U
	Beetle, spider, larva (Pitnus tectus) (concluded)	
232	Lipids, general	u
233	Fatty acids	R
234	Sterols, derivatives	R
235	Calciferol	U
236	Cholestanol	u
237	Cholesterol	U
238	Ergosterol	U
239	Sitosterol	U
240	Zymosterol	u
241	Biotin	R
242	Choline	R
243	Inositol	R(?)
244	Niacin	R
245	Pantothenic acid	R
246	Para-aminobenoic acid	R(?)
247	Pyridoxine group	R
248	Riboflavin	R
249	Thiamine	R
	Blowfly, adult (Calliphora erythrocephala)	
250	Carbohydrates	U
251	Arabinose	U
252	Cellobiose	U
253	Dextrin	u
254	Fructose	U
255	Galactose	U
256	Glucose	U
257	Inulin	U(?)
258	Lactose	u
259	Maltose	U
260	Mannitol	U
261	Mannose	U
262	Raffinose	U
263	Sorbitol	U
264	Sorbose	U
265	Starch	u
266	Sucrose	U
267	Xylose	u
	Cockroach, German, nymph (Blattella germanica)[4]	
268	Gelatin	U
269	Lactalbumin	U
270	Zein	U
271	Protein, total	15-30%
272	Alanine	R
273	Arginine	R
274	Aspartic acid	R
275	Cystine	R(?)
276	Glutamic acid	R
277	Glycine	R
278	Histamine	R
279	Hydroxyproline	R
280	Isoleucine	R
281	Leucine	R
282	Lysine	R
283	Methionine	R(?)
284	Phenylalanine	R
285	Proline	R
286	Serine	R
287	Threonine	R
288	Tryptophan	R(?)
289	Tyrosine	R
290	Valine	R
291	Carbohydrates	32%[3]
292	Dextrin	U
293	Glucose	U
294	Lactose	U
295	Starch	U
296	Sucrose	U
297	Lipids, general	U
298	Fatty acids	R
299	Sterols, derivatives	R
300	Cholesterol	U
301	Biotin	R(?)
302	Choline	R
303	Folic acid group	R
304	Inositol	R
305	Niacin	R
306	Pantothenic acid	R
307	Para-aminobenzoic acid	R
308	Pyridoxine group	R
309	Riboflavin	R
310	Thiamine	R

/1/ Per cent of protein in diet required to maintain growth and development. /2/ Deprived of normally present intracellular symbionts. /3/ Approximate percentage of carbohydrates required in optimum diet. /4/ Also aseptically reared on synthetic diet.

All insect tissues, and diets, contain nitrogen, carbon, oxygen and hydrogen. In addition, phosphorus, sulfur, iron, copper, magnesium, manganese, potassium, calcium and chlorine are probably universally required by insects. A number of other minerals, some only in traces, are consumed and found in the composition of the insect.

R = required; R = not required, U = utilized, U = not utilized; u = poorly utilized.

	Nutrient	Value
	Fly, vinegar fruit-, larva (Drosophila melanogaster)[4]	
311	Casein	U
312	Gelatin	U
313	Protein, total	2-3%
314	Alanine	R
315	Arginine	R
316	Aspartic acid	R
317	Cystine	R
318	Glutamic acid	R
319	Glycine	R
320	Histidine	R
321	Hydroxyproline	R
322	Isoleucine	R
323	Leucine	R
324	Lysine	R
325	Methionine	R
326	Phenylalanine	R
327	Proline	R
328	Serine	R
329	Threonine	R
330	Tryptophan	R
331	Tyrosine	R
332	Valine	R
333	Carbohydrates	U
334	Arabinose	u
335	Cellobiose	U
336	Dextrin	u
337	Fructose	U
338	Galactose	u
339	Glucose	U
340	Inulin	U
341	Maltose	U
342	Mannitol	u
343	Mannose	U
344	Raffinose	U
345	Sorbitol	u
346	Sorbose	u
347	Starch	u(?)
348	Sucrose	U
349	Xylose	u
350	Lipids, general	U
351	Fatty acids	R
352	Sterols, derivatives	R
353	Calciferol	U
354	Cholestanol	u
355	Cholesterol	U
356	Ergosterol	U
357	Sitosterol	u
358	Biotin	R
359	Choline	R
360	Folic acid group	R
361	Inositol	R
362	Niacin	R
363	Pantothenic acid	R
364	Para-aminobenzoic acid	R
365	Pyridoxine group	R
366	Riboflavin	R
367	Thiamine	R
	Mealworm, yellow, larva (Tenebrio molitor)	
368	Casein	U
369	Gelatin	U
370	Lactalbumin	U
371	Zein	U
372	Protein, total	15-45%
373	Lysine	R
374	Tryptophan	R
375	Carbohydrates	80-85%
376	Arabinose	U
377	Cellobiose	u
378	Dextrin	U
379	Fructose	U

	Nutrient	Value
	Mealworm, yellow, larva (Tenebrio molitor) (concluded)	
380	Galactose	U
381	Glucose	U
382	Inulin	U
383	Lactose	u
384	Maltose	U
385	Mannitol	U
386	Mannose	U
387	Raffinose	U
388	Sorbitol	U
389	Sorbose	U
390	Starch	U
391	Sucrose	U
392	Xylose	u
393	Lipids, general	U
394	Fatty acids	R
395	Sterols, derivatives	R
396	Calciferol	U
397	Cholesterol	U
398	Ergosterol	U
399	Sitosterol	U
400	Biotin	R
401	Choline	R (?)
402	Folic acid group	R
403	Inositol	R
404	Niacin	R
405	Pantothenic acid	R
406	Para-aminobenzoic acid	R
407	Pyridoxine group	R
408	Riboflavin	R
409	Thiamine	R
	Mosquito, larva (Aedes aegypti)[4]	
410	Casein	U
411	Alanine	R
412	Arginine	R
413	Aspartic acid	R
414	Cystine	R(?)
415	Glutamic acid	R
416	Glycine	R
417	Histidine	R
418	Hydroxyproline	R
419	Isoleucine	R
420	Leucine	R
421	Lysine	R
422	Methionine	R
423	Phenylalanine	R(?)
424	Proline	R
425	Serine	R
426	Threonine	R
427	Tryptophan	R
428	Tyrosine	R(?)
429	Valine	R(?)
430	Carbohydrates	U
431	Arabinose	U
432	Cellobiose	U(?)
433	Fructose	U(?)
434	Galactose	U(?)
435	Glucose	U(?)
436	Lactose	U(?)
437	Maltose	U(?)
438	Mannitol	U(?)
439	Mannose	U(?)
440	Raffinose	U
441	Sorbitol	U(?)
442	Sorbose	U
443	Starch	U
444	Sucrose	U
445	Xylose	u(?)
446	Lipids, general	U
447	Fatty acids	R
448	Sterols, derivatives	R

	Nutrient	Value
	Mosquito, larva (Aedes aegypti)[4] (concluded)	
449	Calciferol	U
450	Cholestanol	u
451	Cholesterol	U
452	Ergosterol	u
453	Sitosterol	U
454	Zymosterol	u
455	Biotin	R
456	Choline	R
457	Folic acid group	R
458	Inositol	R
459	Niacin	R
460	Panthothenic acid	R
461	Para-aminobenzoic acid	R(?)
462	Pyridoxine group	R
463	Riboflavin	R
464	Thiamine	R
	Moth, Mediterranean flour-, larva (Ephestia kuehniella)	
465	Casein	U
466	Protein, total	45%[1]
467	Carbohydrates	80%[3]
468	Dextrin	U
469	Fructose	U
470	Galactose	U
471	Glucose	U
472	Inulin	U
473	Lactose	U
474	Maltose	U
475	Mannitol	U
476	Raffinose	U
477	Sorbitol	U
478	Sorbose	U
479	Starch	U
480	Sucrose	U
481	Xylose	U
482	Lipids, general	U
483	Fatty acids	R
484	Sterols, derivatives	R
485	Calciferol	U
486	Cholestanol	u(?)
487	Cholesterol	U
488	Ergosterol	u(?)
489	Sitosterol	U
490	Zymosterol	U
491	Biotin	R
492	Choline	R
493	Folic acid group	R
494	Inositol	R
495	Niacin	R
496	Pantothenic acid	R
497	Para-aminobenzoic acid	R
498	Pyridoxine group	R
499	Riboflavin	R
500	Thiamine	R
	Moth, webbing clothes- (Timeola bisselliella)	
501	Casein	U
502	Protein, total	20-80%
503	Carbohydrates	U-R(?)
504	Glucose	U
505	Starch	U
506	Lipids, general	U
507	Fatty acids	R
508	Sterols, derivatives	R
509	Cholesterol	U
510	Biotin	R(?)
511	Choline	R
512	Inositol	R
513	Niacin	R
514	Pantothenic acid	R

	Nutrient	Value
	Moth, webbing clothes- (Timeola bisselliella) concluded	
515	Para-aminobenzoic acid	R
516	Pyridoxine group	R
517	Riboflavin	R
518	Thiamine	R
	Parasite of spruce budworm larva (Pseudosarcophaga affinis)[4]	
519	Amino acids, total	2%[5]
520	Alanine	R
521	Arginine	R
522	Aspartic acid	R
523	Cysteine	R
524	Glutamic acid	R
525	Glycine	R
526	Histidine	R
527	Hydroxyproline	R
528	Isoleucine	R
529	Leucine	R
530	Lysine	R
531	Methionine	R
532	Phenylalanine	R
533	Proline	R
534	Serine	R
535	Threonine	R
536	Tryptophan	R
537	Tyrosine	R
538	Valine	R
539	Glutathione	R
540	Carbohydrates	R
541	Arabinose	u
542	Dextrin	U
543	Galactose	U
544	Glucose	0.5%[5]
545	Glycogen	U
546	Lactose	u
547	Levulose	U
548	Maltose	U
549	Mannitol	u
550	Mannose	u
551	Melezitose	U
552	Raffinose	u
553	Rhamnose	u
554	Sorbose	u
555	Starch	U
556	Sucrose	U
557	Sorbitol	u
558	Trebalose	u
559	Xylose	u
560	Cholesterol	0.1%[5]
561	Fatty acids	0.4%[5]
562	Ribonucleic acid	0.15%[5]
563	Biotin	R
564	Choline	2.0mg[6]
565	Folic acid group	R
566	Inositol	R
567	Niacin	0.3mg[6]
568	Pantothenic acid	0.43mg[6]
569	Para-aminobenzoic acid	R
570	Pyridoxine	R
571	Riboflavin	0.14mg[6]
572	Thiamine	0.1mg[6]
573	Vitamin B_{12}	R
574	Galactose	u
575	Glucose	U
576	Lactose	u
577	Levulose	U
578	Maltose	U
579	Mannitol	u
580	Raffinose	u
581	Sucrose	U
582	Xylose	u

/1/ Per cent of protein in diet required to maintain growth and development. /3/ Approximate percentage of carbohydrates required in optimum diet. /4/ Also aseptically reared on synthetic diet. /5/ Per cent in diet required to maintain optimum growth and development. /6/ mg/100 ml in diet required to maintain optimum growth and development.

Oxygen is essential for all organisms listed. Carbon dioxide is required by all species in this table for which data are available. Certain green forms, e.g., Chlamydomonas moewusii and Anabaena cylindrica, appear unable to grow in darkness. Colorless and green forms grown in darkness require an additional carbon source.

U = utilized; u = poorly utilized; **U** = not utilized; R = required; **R** = not required.

Nutrient	Photosynthetic Forms: Chlamydomonas agilis/reinhardi	C. moewusii	Chlorogonium elongatum	C. euchlorum	Chlorella pyrenoidosa	Euglena anabaena minor	E. deses	E. gracilis	E. gracilis bacillaris	E. gracilis Hyalina	E. klebsii	E. pisciformis	E. stellata	Haematococcus pluvialis	Phacus pleuronectes	Synechococcus cedrorum	Anabaena cylindrica[2]	Colorless Forms: Astasia longa	A. quartana	Chilomonas paramecium	Peranema trichophorum	Polytoma uvella	P. obtusum	P. ocellatum	P. uvella	Polytomella caeca	Prototheca zopfii
Vitamins																											
1 Cobalamin	R	R	R	R	R	R[3]	R[4]	R[5]	R[5]	R[3]	R	R	R[3]	R	R	R	R	R		R							
2 Thiamine	R	R	R	R	R	R[3]	R	R	R	R[3]	R	R	R[3]	R	R	R	R	R		R		R	R	R	R	R	R
3 Other	R	R	R	R	R	R[3]				?			R[3]	R	R	R	R									
Carbon Source: Sugars																											
4 Arabinose		U	U?	U?	u															U?			U			U
5 Glucose		U	U?	U?	U	U	U	U	U	U	U	U				U	U			U?		U	U	U		U
6 Maltose		U	U?	U?	u															U?				U		U
7 Sucrose		U	U?	U?	u	U	U	U			U	U				U				U?				U		U
8 Xylose		U	U?	U?	u															U?				U		U
Carbon Source: Organic Acids (Other than Fatty Acids)[6]																											
9 Citric	U	U			u	U	U	U	U	U			U										U				U
10 Fumaric		U			u					U[6]	U																U
11 Lactic	U	U		U	u	U		U	U	U			U	U				U?	U	U	U	U	U	U	U?	U?	U[6]
12 Malic	U	U		U	u	U	U	U	U[6]	U	U	U		U				U?	U	U	U		U	U?	U	U	U
13 Phosphoglyceric	U	U				U	U	U		U[6]	U	U											U				
14 Pyruvic		U		u	u	U	U	U	U		U	U						U?	u	U	U	U	u	U	u	u	U[6]
15 Succinic	U	U		U	u	U	U	U	U[6]	U?			U			U		U?	U	U		U		U	U?	U?	u	U
Carbon Source: Alcohols[7]																											
16 i-Butanol								U		U								u		U		U	U	U	U	U	U
17 n-Butanol		U						U		U								U	U	U		U	U	U	U	U	U
18 Ethanol		U	U	U			U	U		U								U	U	U	U	U	U	U	U	U	U
19 Glycerol		U				U	U						U	U													U
20 n-Hexanol								U		U								U	U	U			U		U		
21 Methenol								U		U								U	U		U	U	U	U	U	U	U
22 i-Pentanol								U		U								U		U[8]			U		U		
23 n-Pentanol								U		U								U			U	U	U	U	U	u	U
24 i-Propanol								U		U								U	U	U	U	U	U	U	U	U	U
25 n-Propanol								U		U								U	U	U[8]	U	U	U	U	U	U	U
Carbon Source: Fatty Acids[9]																											
26 Acetic	U	U	U	U	u	U	U	U	U	U	U	U	U	U			U	U	U	U	U	U	U	U	U	U	U
27 i-Butyric	U	U		U		U	U	U		U			U					u	u	U	U	U	U	U	U	U	U
28 n-Butyric	U	U	U	U		U	U	U	U	U	U	U	U	U				u	u	U	U	U	U	U	U	U	U
29 i-Caproic								u		u								u	U	U		U	U	U	U	u	U
30 n-Caproic	U		U	U		U	U[10]	U		U			U[10]		U			U	U	U	U	U	U	U	U	U	U
31 n- Decylic								U		U								u				U	U	U	U	U	U
32 n-Heptylic						u[10]	u[10]	U		U			u[10]					U	U	u		U	U	U	U	U	U
33 n-Nonylic						u[10]	u[10]	U		u			u[10]					U		u		U	U	U	U	U	U
34 n- Octylic						u[10]	u[10]	U		U			u[10]					U		U		U	U	U	U	u	U
35 Propionic	U	U	U	U	u	U	U	U		U	U	U	U	U				U	U	U	U	U	U	U	U	U	U
36 i-Valeric						U	U	U		U			U					U	u	u		U	U	U	U	U	u
37 n-Valeric	U	U	U	U		U	U	U		U			U	U				U	U	U	U	U	U	U	U	U	U
Nitrogen Sources[11]																											
38 α-Alanine					U	U	U	U[12]	U[12]		U[13]	U											u	U	U		
39 Ammonium	U	U	U	U	U	U	U	U[12]	U[12]	U[12]	u	U[13]	U	U	U	U		U		U		U	U	U	U	U	U
40 β-Arginine						U	U	U		U		U[13]	U										U	U			
41 L-Asparagine	U[12]	U		U[12]	U	U	U	U[12]	6,12	6,12	U	U[14]	U	U[12]									u	U		U	
42 α-Glutamic acid[15]		U	U		U	U	U	U[12]	U	U	U	U[13]	U		U								U	U		U	
43 Glycine	U[12]			U	U	U	U	U[12]				U[13]	U	U[12]											U		
44 Histidine						U	U	U[12]				U[13]	U												U		
45 L-Leucine						U	U	U[12]				U[13]	U										u	U			
46 ε-Lysine						U	U	U				U[13]	U										u	U			
47 Nitrite	U	U	U	U	U	U	U	u	U	U	u	U[13]	U	u	U	U				?		U	U	U	U	U	
48 Peptone	U[12]	U	U[12]	U[12]		U	U	U[12]	U[12]	U[12]	U	U	U	U[12]	U			U	U	U	U	U	U	U	U	U	U
49 DL-Phenylalanine						U	U	U[12]				U[13]	U										U	U			
50 DL-Proline						U	U	U[12]				U[13]	U										u	U			
51 DL-Serine						U	u	U[12]				U[13]	U										u	U			
52 L-Tryptophan						U	U	U				U[13]	U										u	U			
53 L-Tyrosine						U	U	U				U[13]	U														
54 DL-Valine						U	U	U[12]				U[13]	U														

/1/ Additional components not listed: fructose, U; galactose, u; lactose, U; mannose, u; inulin, u; methyl-γ-D-glucoside, u; methyl-β-D-glucoside, U; starch, u; cis-aconitic, u; inositol, u; dulcitol, u; mannitol, u; sorbitol, u; L-aspartic acid, u. /2/ Additional components not listed: mannitol, **U**; elementary nitrogen, U. /3/ The organism has been reported not to require vitamins; it is possible that this condition, as in other species of Euglena, exists only after adaptation to vitamin-less media. /4/ Pseudo-cobalamin also utilized. /5/ It has been shown that Prototheca zopfii and Euglena gracilis utilize most of these acids only at pH 3.5-5.5; the majority of the negative results tabulated may not be significant because they were obtained in media having a pH near neutrality. /6/ Utilized only at pH 3.0-5.5. /7/ Optimal concentrations are similar to those of the corresponding fatty acid (cf Fn 9). /8/ Inadequate for growth in mineral media. /9/ The following are average ranges of concentration (g per 100 ml media) at which fatty acids are utilized and non-toxic: acetic, propionic, butyric and isobutyric acids, 0.1-0.2; valeric and isovaleric acids 0.05-0.1; caproic, isocaproic, heptylic and octylic acids, 0.01-0.03; nonylic acid, 0.01; decylic acid, 0.005-0.008. Some negative results tabulated may be incorrect if toxic concentrations were employed. Toxicity usually increases with length of carbon chain and with decrease in pH of medium. /10/ Employed at toxic concentrations. /11/ For photosynthetic species data pertain to utilization in light. Some amino acids may serve also as carbon sources. /12/ Also utilized in darkness. /13/ Negative results may not be valid because tests were conducted in media lacking thiamine. /14/ Growth is obtained only if thiamine is present. /15/ When utilized, a good carbon source.

175. SUGAR UTILIZATION FOR GROWTH: FILAMENTOUS FUNGI

Interpretation of the amount of growth obtained on different sugars is often subject to error. Low yields may be attributed to slow utilization of the sugar involved, but are frequently caused by other factors. It is possible that some organisms listed as not utilizing a certain sugar, or utilizing it poorly will be found to utilize it well under different nutritional conditions. U = utilized; u = utilized slowly; V = utilization slight or none.

	Species	a-Glucose	a-Fructose	a-Mannose	a-Galactose	b-Sorbose	L-Arabinose	b-Xylose	Sucrose	Maltose	Lactose	Cellobiose	Raffinose
1	Achlya flagellata	U	U	U	V	U	V	U	U	U	V		V
2	Allomyces sp	U	U	U	U	V	V	V	U	V	V		
3	Alternaria solani	U	U	U	U	U	U	U	U	u	u		
4	Aspergillus clavatus	U	U	U	u	V	U	U	u	U	V		
5	A. elegans	U	U	U	u	u	U	U	U	u	u	U	
6	A. niger	U	U	U	u	U	U	U	U	u	U	U	
7	A. oryzae	U	U	U	u	u	u	U		V	u		
8	A. rugulosus	U	U	U	u	U	U	U	U	u	u	U	
9	Blakeslea trispora	U	U	U	U				U	u	U		
10	Blastocladia pringsheimii	U	U	U	V	U	V	V	U	U	V		
11	Botrytis cinerea	U	U	U	U	U	U	U	U	U	U	U	
12	Ceratostomella fimbriata	u	u	u	V	u	u	U	U	V	u	V	
13	Chaetomium convolutum	U	U	U	U	V	U	u	U	V	u	V	
14	C. globosum	U	U	U	u	u	U	u	U	V	u	V	
15	Choanephora cucurbitarum	U	U	U	U	V	u	u	U	V	U	V	
16	Chytridium sp	U	U	U	U	V	U	V	V	V	V	V	
17	Claviceps purpurea	U	U				U	U		U			
18	Coccidioides immitis	U	U	U	U		V	u	U	V	U	u	
19	Colletotrichum lindemuthianum	U	U	U	U	V	u	u	U	V	U	u	
20	Collybia velutipes	U	U	U	u	V	u	u	U	V	u	V	
21	Cordyceps militaris	U	U	U	U	V	u	U	U	u	V	U	u
22	Dendrophoma obscurans	U	U		U	V	u	U	U	V	U	u	
23	Diaporthe phaseolorum batat.	U	U				U	U					
24	Dictyuchus monosporus	U	V	U	V		V	V	U	V		V	
25	Diplodia macrospora	U	U	U	U			U	U	u			
26	B. natalensis	U	U	U	U			U	U	u			
27	Endoconidiophora fagacearum	u	u	U	u	V	u	u	V	U	V	u	u
28	Endothia parasitica	U	U	U	u	u	u	u	U	V	U	V	
29	Entomophthora spiculata	U	u	U	u	U	U	V	U	V	U	V	
30	E. coronata	U	U	U	u	V	V	V	V	V	V	V	
31	Fusarium conglutinans	U	U	U	u	U	U	U	U	u	u	u	
32	F. culmorum	U	U	U	u	u	U	U	U	u	u	u	
33	F. lycopersici	U	U	U	U	U	U	U	U	u	u	u	
34	F. medicaginis	U	U	U	u	U	U	U	U	u	u	u	
35	F. nivale	U	U	U	u	U	U	U	U	u	U	u	
36	F. niveum	U	U	U	U	U	U	U	U	U	U	U	
37	F. trycheiphilum	U	U	U	U	u	U	U	U	u	U	u	
38	Glomerella cingulata	U	U	U	U	u	U	U	U	u	U	u	
39	Hellicostylum pyriforme	U	U	U				U	u	u			
40	Helminthosporium sativum	U	U	U	u	u	u	U	U	u	u	u	
41	Lenzites saepiaria	U	U	U	u	u	V	u	u	u	V	u	
42	L. trabea	U	u	U	u	u	u	U	u	U	U	u	
43	Leptomitus lacteus	U	U		V			V	U				
44	Macrochytrium sp	U	U	U	V	U	V	U	V	U	V		

	Species	a-Glucose	a-Fructose	a-Mannose	a-Galactose	b-Sorbose	L-Arabinose	b-Xylose	Sucrose	Maltose	Lactose	Cellobiose	Raffinose
45	Melanconium fuligineum	U	U	U	U	u	u	u	U	U	U	u	
46	Memnoniella echinata	U	U	U	U	U		U	U	U	U	U	U
47	Monilinia fructicola	U	U	U	U	U	u	U	U	U	U	U	U
48	Monosporium apiospermum	U	U	U	U	U	u	U	U	U	U	U	u
49	Morchella esculenta	U	U	U	U		U	U	U	U	U	U	U
50	Mucor ramannianus	U	U	U	U	U	U	U	U	U	U	U	V
51	Neocosmospora vasinfecta	U	U	U	U	U	U	U	U	U	U	U	u
52	Ophiobolus graminis	U	u	U	U	V	u	u	U	U	U	u	u
53	Penicillium chrysogenum	U	U	U	U	V	U	U	U	U	U	U	V
54	P. digitatum	U	U	U	U	V	U	u	U	U	U	U	V
55	P. expansum	U	U	U	U	u	u	U	U	U	U	U	U
56	P. spiculosporum	U	U	U	U	u	U	U	U	U	U	U	V
57	Phoma betae	U	U	U	U	u	U	U	U	U	U	U	V
58	Phycomyces blakesleeanus	U	U	U	U	u	U	U	U	U	U	V	V
59	Phymatotrichum omnivorum	U	U	U	V		V	U	U	U	V		
60	Phytophthora cactorum	U	u	u	V				U	U	V		
61	P. erythroseptica	U	u	U	V				U	U	V		
62	P. fagopyri	U	u	u	V				u	U	V		
63	P. infestans	U	U	U	V	V	V	u	u	u	V	V	V
64	Pilaira moreaui	U	U	U	U				U	U	V		
65	Polyporus albellus	U	u	U	u	u	U	U	V	U	u	V	V
66	P. versicolor	U	U	U	u	u	U	u	U	U	u	U	u
67	Pythiogeton uniforme	U	U	U	U	U	U	U	U	U	U	U	U
68	Pythiomorpha gonapodyoides	U	U	u	V				u	U	V		
69	Pythium ascophallon	U	u	U	V				U	U	V		
70	Rhizophlyctis rosea	U	U	U	V	U	V	U	U	U	V	U	
71	Rhizopus nigricans	U	U	U	U				U	U	V		
72	R. sulnus	U	U	U	U				U	U	V		
73	Rosellinia arcuata	U	U	U	U				U	U	V		
74	Saprolegnia delica	U	U	U	V		V	U	U	U	V		V
75	S. ferax	U	U	U	V		V	U	U	U	V		V
76	Schizophyllum commune	U	U	U	U		U	U	U	U	U	U	U
77	Schizothecium longicolle	U	U	U	V	V	U	U	U	V	U	V	V
78	Sclerotium delphinii	U	U		U		U	U	U	U	U		
79	Septoria nodorum					u	V		u	u			
80	Sordaria fimicola	U	U	U	u	V	u	u	U	V	u	U	V
81	Sphaeropeis malorum	U	U	U	U	u	u	u	U	U	U	U	V
82	Stysanus stemonitis	U	u	U	U	U	U	U	U	U	U	U	V
83	Syncephalastrum racemosum	U	U	U	U	u	u	U	U	V	U	u	V
84	Thielavia basicola	U	U	U	U				U	U	V		
85	Thraustotheca clavata	U	U	U	V				U	U	V		
86	Typhula variabilis	U	U	U	u				U	U	V		
87	Ustilago violacea	U	U	U	U		V	U	U	U	V	U	V

176. ORGANIC COMPLEXES REQUIREMENTS: BACTERIA

R = required; R = not required.

	Species	Vitamin A	Ascorbic Acid	Biotin	Choline	Cobalamin	Vitamin B6	Folic Acid	Inositol	Vitamin K	Niacin	Pantothenic Acid	Para-aminobenzoic Acid	Pyridoxine Group	Riboflavin	Thiamine
1	Aerobacter aerogenes	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
2	Bacillus alvei			R						R						
3	B. anthracis			R						R						
4	B. brevis			U						R						
5	B. cereus			R						R						
6	B. cereus mycoides			R						R						
7	B. circulans			R						R						
8	B. coagulans			R						R^2						
9	B. licheniformis			R						R						
10	B. macerans			R						R						
11	B. megaterium			R						R						
12	B. pasteurii			R^9						$R^?$						
13	B. polymyxa			R						R						
14	B. pumilis			R						R						
15	B. sphaericus			R^9						R						
16	B. subtilis			R						R						
17	B. subtilis niger			R						R						
18	Brucella abortus	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
19	B. melitensis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
20	B. suis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
21	Erwinia amylovora	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
22	E. tracheiphila	R	R	R	R	R	R	R	R	$R^?$	R	R	R	R	R	R
23	Escherichia coli	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

	Species	Vitamin A	Ascorbic Acid	Biotin	Choline	Cobalamin	Vitamin B6	Folic Acid	Inositol	Vitamin K	Niacin	Pantothenic Acid	Para-aminobenzoic Acid	Pyridoxine Group[1]	Riboflavin	Thiamine
24	Hemophilus influenzae[4]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	Lactobacillus															
25	Hetero-fermentative[5]			R			$R^{6.6}$			$R^{3.7}$		R	R	$R^{4.7}$	$R^{3.7}$	R
26	Homo-fermentative[5]			R			$R^{6.6}$			$R^{3.7}$		R	R	$R^{4.7}$	$R^{3.7}$	R
27	Leuconostoc citrovorum			R						R		R	R	R^9	$R^{7.9}$	$R^{7.9}$
28	L. dextranicum			R						R		R	R	R^9	$R^{7.9}$	$R^{7.9}$
29	L. mesenteroides			R						R		R	R	R^9	$R^{7.9}$	$R^{7.9}$
30	Pasteurella multocida[10]			R^3										R^{11}		
31	P. pseudotuberculosis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
32	P. tularense															R^{12}
33	Proteus morgani			R						R						
34	P. vulgaris			R						R						
35	Salmonella cholerae-sius	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
36	S. typhimurium	R	U	R	R	R	R	R	R	R	R	R	R	R	R	R
37	S. gallinarum															R
38	S. pullorum	R	R	R	R	R	R	R	R	R	R^3	R	R	R	R	R
39	S. paratyphi-muelleri	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
40	S. typhosa	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
41	Serratia marcescens	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
42	Shigella alkalescens	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
43	S. paradysenteriae										R^{13}	R^3				
44	S. sonnei										R^{13}	R^3				
45	Staphylococcus albus			R						R		R^9		R^9		R
46	S. aureus			R						$R^?$		R^9		$R^?$		R

/1/ Includes pyridoxine, pyridoxal, pyridoxamine. /2/ One strain only. /3/ Various strains. /4/ Requires hemin, diphosphopyridine. R,parainfluenzae requires diphosphopyridine nucleotide,putrescine. /5/ Some strains also require pyridoxal phosphate, pantethine. /6/ Or nucleotides. /7/ Occasional requirement as growth stimulant. /8/Nicotinic acid for some strains only. /9/ Occasional requirement for growth. /10/ For P. pestis: only hemin required for aerobic types; no known requirements for anaerobic types. /11/ Nicotinamide. /12/ Thiamine diphosphate; adenosine also required. /13/ Usually required.

ORGANIC COMPLEXES REQUIREMENTS: FUNGI

Data are applicable to organic complexes (vitamins) which must be supplied to each organism in its substrate. In each case, the organism synthesizes all other vitamins needed in its metabolism. Different isolates of the same species may have different requirements.

B = biotin; I = inositol; N = nicotinic acid; Pn = pantothenic acid; Pa = para-aminobenzoic acid; Px = pyridoxine; T = thiamine; O = none.

	Species	Vitamins Required
1	Abaidia spp[1]	O
2	A. ramosa	T[2]
3	Achlya conspicua	O
4	Allescheria boydii	B
5	Allomyces arbuscuius	T[3]
6	Alternaria solani	O
7	Amanita pantherina	T[4]
8	Aphanomyces campto-stylus	O
9	A. phycophilus	T
10	Armillaria mellea	O
11	Ascobolus spp[5]	O
12	Ascochyta pisi	O
13	Ascoidea rubescens	Px, T
14	Ashbya gossypii	B, I, T
15	Aspergillus spp[6]	T
16	Basidiobolus ranarum	O
17	Blakeslea trispora	T[2]
18	Blastocladia pringsheimii	B, N, T
19	Blastomyces brasiliensis	T
20	B. dermatitidis	O
21	Botetus spp[7]	T
22	Botrytis allii & cinerea	O
23	Brettanomyces bruxellensis	Px
24	Bulgaria inquinans	T
25	Calocera viscosa	T
26	Candida chevalieri	O
27	C. pseudotropicalis	B, N, Pn, T
28	Cephalosporium recifei	O
29	Ceratostomella spp[8]	B, Px, T
30	Ceratostomella spp[9]	Px, T
31	C. adiposum	I
32	C. rostrocylindrica	O
33	C. stenoceras	T
34	Cercospora apii & beticola	O
35	Chaetocladium brefeldii	T
36	Chaetomium spp[10]	O
37	C. convolutum	B, T
38	Chaetostylum fresenii	O
39	Chalaropsis thielavioidea	T
40	Choanephora cucurbitarum	T
41	Circinella aspera & spinosa	O
42	Cladosporium herbarum & werneckii	O
43	Clavaria ligula	T
44	Collocybe spp[11]	T
45	Clitopilus prunulus	T[4]
46	Coemansia interrupta	B, T
47	Colletotrichum circinans	O
48	C. lindemuthianum[12]	O
49	Collybia spp[13]	T
50	C. dryophila	B, T
51	Coprinus spp[6]	T
52	Cordyceps militaris	O
53	Coryne sarcoides	B, T
54	Cudonia circinans	T
55	Cunninghamella spp[14]	O
56	Cynthus striatus	T
57	Dacryomyces stillatus	T
58	Daedalea spp[15]	T
59	Daldinia concentrica	O
60	Dasybolus immersus	T
61	Debaryomyces spp[16]	B
62	D. membranefaciens	B, T
63	Dematium chodati & pullulans	O
64	D. nigrum	T[2]
65	Dendromyia obscurans	T
66	Dermatea balsamea	T
67	Diaporthe strumella	O
68	Diplodia macrospora	B
69	Dipodascus uninucleatus	B, T
70	Dothidella quercus	O
71	Endobotrya parasitica	B, T
72	Entyloma arnoseridis	O
73	Epichloë typhina	T[17], T
74	Epidermophyton floccosum	O
75	Eremascus fertilis	O
76	Eremothecium ashbyi	B, I, T
77	Exobasidium vaccinii	T
78	Flammula carbonaria & persistens	T
79	Fomes spp[18]	T
80	F. fraxineus	O
81	Fusarium spp[19]	B
82	F. avenaceum[20]	B
83	Ganoderma lucidum	O
84	Glenosporella loboi	O
85	Gliocladium fimbriatum	O
86	Gloeocystidium roseo-cremeum	T
87	Glomerella cingulata	O
88	Gloeosporium aeruginosa	O
89	Gymnoascus setosus	O
90	Hansenula anomala	T
91	Haplosporangium parvum	O
92	Helminthosporium spp[21]	O
93	Helvella infula	T
94	Hemitopsora stellata	O
95	Histoplasma capsulatum	O
96	Hormiscium dermatitidis	T
97	Hormodendrum algeri-ensis	T
98	H. langeroni	O
99	Hydnum spp[22]	T
100	H. corralloides	O
101	Hypholoma fasciculare	T
102	Hypoxylon pruinatum	B, T
103	Kloeckera brevis	B, I, N, Pn, Px, T
104	Lachnum pygmaeum	B, T
105	Lactarius deliciosus	T
106	Lambertella spp[23]	B[17], T
107	Lentinus emphalodes	T
108	Lenzites spp[24]	T
109	Leptosphaeria nitida & pera	T
110	Lophodermium pinastri	B, I, T
111	Madurella americana	O
112	Malassezia furfur	T
113	Marasmius spp[25]	T
114	M. perforans	B, T
115	Melanconium betulinum	B, I, T
116	Melanospora destruens	B, T
117	Memnoniella echinata	B
118	Merulius lacrymans	B
119	Microsporum spp[26]	O
120	M. audouini	N, Px[17]
121	Monascus purpureus	O
122	Montlinia fructicola	O
123	M. laxa	T[17]
124	Mortierella spp[6]	O
125	Mucor spp[27]	T
126	M. mucedo	T
127	Mycocterma lipolytica	T
128	M. valida	B
129	Mycosphaerella confusa	O
130	M. grossulariae	O
131	M. sentina	T
132	Mycotorula lactis	N
133	Nectria coccinea	B, T[17]
134	Nematospora coryll	O
135	N. gossypii	B, I, T
136	Neocosmospora vasinfecta	O
137	Neurospora spp[28]	B
138	Nyctalis asterophora	T
139	Ophiobolus graminis	B, T
140	O. miyabeanus	O
141	O. oryzinus	B
142	Ophiostoma catonianum	Px, T[17]
143	O. caeruleum	T
144	O. fagi	B[17], Px
145	Panaeolus campanulatus	T
146	Panus stipticus & torulosus	T
147	Parasitella simplex	T
148	Penicillium digitatum	B, Pn, Px, T
149	Penicillium spp[29]	O
150	Peniophora spp[30]	T
151	Phacidium infestans	T[17]
152	Phialophora spp[31]	T
153	Pholiota adiposa	T[17]
154	P. mutabilis & squarrosa	T
155	Phoma spicola & betae	O
156	Phycomyces blakesleeanus	T
157	P. nitens	T
158	Phymatotrichum omnivorum	O
159	Phytophthora spp[6]	T
160	Pichia sclerodermum algeri	B
161	P. belgica	B, I, Px, T
162	P. dombrowaki	T
163	P. kluyveri	B, T
164	Piedraia hortai	T
165	Piptocephalis freseniana	T
166	Piricularia oryzae	B, T
167	Pityrosporum ovale	B, T
168	Pleurage curvicolla	B, T
169	Pleurotus corticatus	T[2]
170	Polyporus grasqui	O
171	Polystictus versicolor	T
172	Psalliota bispora	B or T
173	P. campestris	O
174	Pseudopezizа ribis	B
175	Pyronema confluens	T
176	P. domesticum	O
177	Pythiomorpha oryzae	T
178	Pythium spp[32]	O
179	Pythium spp[33]	T
180	Rhizopogon roseolus	B[17], T
181	Rhizopus spp[6]	O
182	Rhodotorula spp[34]	T[2]
183	R. aurantiaca	Pa
184	R. aurea & glutinis	O
185	Roselinia arcuata	B
186	R. necatrix & thelena	O
187	Saccharomyces carlsbergensis	Px
188	Saccharomyces chodati	B, Pn, Px
189	Saccharomycodes ludwigii	B, I, N, Pn, Px, T
190	S. oviformis	B, Pn, Px
191	S. tubiformis	B, Pn
192	S. uvarum	B, I
193	Saprolegnia delica & mixta	O
194	Schizophyllum commune	T[2]
195	Schizosaccharomyces pombe	B, I, N, Pn
196	Schwanomyces occidentalis	B
197	Sclerotinia camelliae	B, I, T
198	S. minor	B[17], T[17]
199	S. sclerotiorum	O
200	Sclerotium delphinii	T[2]
201	Septoria spp[35]	O
202	S. spil	T[2]
203	Sistotrema confluens	T
204	Sordaria fimicola	B
205	Spathularia flavida	B, Px, T
206	Sporotrichophora gossypii	O
207	Sphaerobolus stellatus	O
208	Sphaeropsis malorum	O
209	Sphaullina trifolii	T
210	Sporotrichum spp[36]	O
211	S. schenckii	T
212	Stachybotrys atra	B
213	Stereum frustulosum	T[37]
214	Stromatinia similacinae	T[17]
215	Syncephalastrum cinereum	O
216	Thamnidium elegans	O
217	Thielaviopsis basicola	T
218	Telletia horrida	T[4]
219	T. levis	O
220	T. tritici	O
221	Torulaspora delbrueckii	B
222	T. fermentati	B
223	Torulopsis candida	B
224	T. dattila	B, Px, T
225	T. kefyr	N
226	T. laurentii & neoformans	T
227	Trametes spp[38]	T
228	Trichoderma spp[39]	T
229	Trichophyton spp[40]	O
230	Trichophyton spp[41]	T
231	T. faviforme	I, T
232	Trichosporon beigelii	B, T
233	T. minor	T
234	Tuberia furfuracea	T
235	Typhula variabilis	T
236	Ustilago spp[42]	T
237	Ustilago spp[43]	T
238	Ustulina vulgaris	O
239	Valsa ceratophora	T
240	V. pini	B, I, T
241	Venturia inaequalis	O
242	Xylaria arbuscula	O
243	X. hypoxylon	T
244	Zygorhynchus spp[44]	O
245	Zygosaccharomyces spp[45]	B, T
246	Z. lactis & marxianus	B, N
247	Z. sadsonii & pastori	B, Pn
248	Z. japonicus	B, I, Pn, T
249	Z. pini	B
250	Z. priorianus	B, I, Pn

/1/ Spp: cerulea, glauca, orchidis, repens, spinosa. /2/ Required only pyrimidine portion of molecule. /3/ Plus an unknown "cofactor" which is neither nicotinic acid nor biotin. /4/ Can be replaced by pyrimidine + thiazole. /5/ Spp: demidatus, furfuraceus, leveillei. /6/ All species tested. /7/ Spp: elegans, granulatus, luteus, piperatus, variegatus, viscidus. /8/ Spp: fimbriata (2 isolates require thiamine only), ipa, microspora, montium, penicillata, pinceisperda, pini. /9/ Spp: multiannulata, phiranmalis, pteridicola, pseudotsugae (partial requirement for thiamine). /10/ Spp: boetrychodes, cochlioides, elatum, globosum. /11/ Spp: alexandri, aurantiaca, clavipes, cyathiformis, geotropa, infundibuliformis, nebularis, odora, pithyophila. /12/ Certain isolates; certain other isolates have a partial requirement for inositol. /13/ Spp: ambusta, butyracea, ruberos (cf Fn 2). /14/ Spp: bertholletiae, echinulata, elegans. /15/ Spp: confragosus, cuperia, unicolor. /16/ Spp: fabryi, guilliermondii, hudelii, membranefaciens, subglobosus. /17/ Partial requirement, some synthesis of the vitamin presumably takes place. /18/ Spp: annosus, igniarius, pinicola. /19/ Most species tested. /20/ One strain only. /21/ Spp: gramineum, sativum, victoriae. /22/ Spp: surfacalpium, corrugatum, erinaceus. /23/ Spp: cormi-marie, hicoriae, pruni, viburni. /24/ Spp: abietina, trabea (cf Fn 17); betulina, saepiaria. /25/ Spp: alliaceus, chordalis, epiphyllus, foetidus, futvo-bubilleosa, graminum, perforans, peronatus, putillus, ramealis, rotula, scorodonius. /26/ Spp: canis, ferrugineum, fulvum. /27/ Spp: circinelloides, genevensie, griseollicinus, hiemalis, mucilaginues, stolonifer, venata. /28/ Spp: crassa, sitophila, tetrasperma. /29/ All other species tested. /30/ Spp: candida, fraxinea, jumipericola, septentrionalia, violaceo-livida. /31/ Spp: compactum, jeanselmei, pedrosoi, verrucos. /32/ Spp: debaryanum, dellense, graminicolum, hyphalasticton, intermedium, irregulare-mamillatum, sclerotiophum, splendens. /33/ Spp: aecophallon, polymostum; arrhenomanes (cf Fn 37); butleri, oligandrum, polyclados (cf Fn 2). /34/ Spp: aurentiaca; flava, mucilaginos, rubra, sonnleri (cf Fn 2). /35/ Spp: azalese, callistephi, chrysanthemella, podorum. /36/ Spp: beurmanni, councilmanni, gougeroti. /37/ Requires only thiazole portion of molecule. /38/ Spp: cinnabarina, heteromorpha, serialis. /39/ Spp: albohrunneum, flavobrunneum, imbricatum, nubum, peroxanthum, pessundatum. /40/ Spp: rubrum, sabouraudi, tonsurans. /41/ Spp: interdigitale, roxaceum, sulfureum, violaceum. /42/ Spp: pinguiculae, ecabricsae, vinosa, violacea. /43/ Spp: avenae, bromivora, hordei, levis, nuda, striiformis, tritici, zeae. /44/ Spp: dangeardi, exponens, heterogamus, moelleri. /45/ Spp: bisporus, mandshuricus.

This table illustrates the ability (or inability) of certain yeasts to utilize nutrients in the following capacities: (1) fermentation, involving the production of gas, of six sugars; (2) assimilation of various carbon compounds; (3) nitrate assimilation; and (4) growth in a vitamin-free medium.
+ = production of gas (fermentation), or growth (assimilation); - = no production of gas (fermentation), or no growth (assimilation); L = latent growth; V = variable reactions; 1/3 = fermentation of 1/3 of raffinose molecule; 3/3 = melibiose also fermented.

| | Yeast Species | Fermentation | | | | | | Assimilation of Carbon Sources | | | | | |

If an organism cannot achieve typical growth, health, or reproduction in the absence of an element, the element is listed as R (or r). If addition of ao element not required improves growth, health or reproduction, the element is listed as s. Accumulation in the tissues of an organism is not, alone, taken as sufficient evidence of requirement. Characterizations are subject to change with further study and increasing purity of materials.
R = Required by all forms studied; U = Not required by any forms studied; r = Required by one or more species or strains; "u" = Utilized as effectively, replaces wholly or is interchangeable with another element for one or more species or strains; uc = Can partially replace or spare another element for one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; a = Accumulated in the tissue of one or more forms; c = Commonly present in the food of some forms and in the tissues at similar concentrations but requirement is uncertain.

	Nutrient	Higher Green Plants[1]	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates[2]	Protozoa[3]	Invertebrates		Vertebrates
									Insects	Other	
1	Aluminum	r,s,a	U	U	U,uc[4]	U	U	U	U		U
2	Arsenic	U	U	U	U	U	U	U	U	a	U
3	Boron	R	U,s	U	r	r	r?	U	U	U	U
4	Bromine	U	U	U	U	U,a	U	U	r?[5]	a?	R
5	Calcium	R	r,s,a	r,uc[6]	r,s	R	r	R	r,c	r	R
6	Carbon	R	R	R	R	R	R	R	R	R	R
7	Chlorine	r,s	U	U	U	a	U	U	r,c	r	R
8	Chromium	U	U	U	uc[7]	U	U	U	U		U
9	Cobalt	r	r	uc[8]	r	r	r	r	r?,s?		r
10	Copper	R	R	r	r,uc[4]	r	r	r	r,c	r	r
11	Fluorine	U,a	U	U	U	U	U	U	U	a	U,s
12	Gallium	r	r,s	U	U	U	U	U	U	U	U
13	Hydrogen	R	R	R	R	R	R	R	R	R	R
14	Iodine	U,s	U	U,s	U,s	U,s	U	U	U	r?,a	R
15	Iron	R	R	R	r,uc[4]	R	R	R	R	r	R
16	Magnesium	R	R	R	r	R	R	R	R	R	R
17	Manganese	R	r,s	r,uc[6]	r,u=	r	r	r	r,c,a	r[8]	R
18	Molybdenum	R,a	R[9],s	r	r[9]	r[9]	U	U	U		R[10]
19	Nitrogen	R	R	R	R	R	R	R	R	R	R
20	Oxygen	R	R	R	R	R	R	R	R	R	R
21	Phosphorus	R	R	R	R	R	R	R	R	R	R
22	Potassium	R	R	r	r	R,a	R	R	r,c,a	R	R
23	Rubidium	U	U	U	u=11	U	U	U	U		U
24	Selenium	U,a	U	U	U	U	U	U	U		U
25	Silicon	r								r	
26	Sodium	r?,s,a	U	U	r	U,a	U	r	r?,c		R
27	Strontium	U	U	U	uc[12]	U,u=	U	U	U		U
28	Sulfur	R	R	R	R	R	R	R	R	R	R
29	Tungsten	U	s	U	U	U	U	U	U		U
30	Vanadium	U	U,s	U	uc[13]	U	U	U,s?	U	r[14]	U
31	Zinc	R	R	r	r,u=	r	r	r	r?,a	R	R

/1/ Spermatophytes (the intact plant). /2/ = Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including the colorless phytoflagellates. /4/ uc = Mn or Cr for Aerobacter aerogenes. /5/ Occurs as a micronutrient of certain corals as di-bromotyrosine. /6/ "u=" = Ca in yeast cocarboxylase. /7/ "u" = Mn for Aerobacter aerogenes. /8/ In blood respiratory pigment of Pinna squamosa (mollusk). /9/ R for NO_3^- utilization by some fungi and some algae; R for N_2 fixation by some bacteria and algae. /10/ "Xanthine oxidase factor." /11/ "u=" = Ca by some. /12/ "u=" = Ca by Azotobacter. /13/ uc = Mo in N_2 fixation. /14/ In blood pigment of certain tunicates (Chordata).

180. NUTRIENTS: GENERAL NITROGEN SOURCES (SUMMARY)

R = Required by all forms studied; U = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by all forms studied; v = Not utilized by any forms studied; u = Utilized by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; * = Serves as adequate or partial N-source for one or more species or strains; ** = Simplest adequate N-source for one or more species or strains.

	Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Protozoa	Invertebrates		Vertebrates
									Insects	Other	
	Inorganic Nitrogen Sources										
1	Nitrogen, molecular, N_2	u[1]	U,u?[2]	U	u=s[3]	U,u=[4]	U	U	U		U
2	Ammonia, -um, NH_3, $-NH_4+$	U,U**	rm,u=s[5]	U,u**	U,u*	U,u=[6]	U,U**	r,u**	U,u?	U,u?	
3	Hyponitrite, $HN_2O_2^-$ or $-N_2O_2^=$	U,u[8]	U,s	U	U,u[9]	U	U	U	U	U	
4	Nitrite, $-NO_2^-$	U,u=[10]	rm,u=s[11]	U,u*	U,u*	U,u=[12]	U	U	U	U	
5	Nitrate, $-NO_3^-$	U,U*	rm,u=s[13]	U,u=[14]	U,u=[15]	U,U*	U,u*	U,u	U	U	
6	Nitrohydroxamate, $-HN_2O_3^-$	U,u=[16]	U,u=[17]	U	U	U	U	U	U	U	
7	Cyanide, $-CN^-$	U	U,u=[18]	U	U	U	U	U[19]	U[19]	U[19]	
8	Thiocyanate, $-CNS^-$	U	U,u?	U	U,u	U	U	U	U	U	
9	Cyanamide, $-NHCN^-$	U	U,u=[20]	U	U,u=[20]	U	U	U	U	U	
	Organic Nitrogen Sources										
10	Oximino compounds, $RONH_2$	U,U=[21]	U,u*	U,u?	U,u=[22]	U=[23]	U	U	U	U	
11	Amines, RNH_2	U	U,u*	U,u*	U,u*	U,u=[24]	U	U	U	U	
12	Acid imides, $(RCO)_2NH$	U	U	U	U,u*	U	U	U	U	U	
13	Acid amides, $RCONH_2$	U,u=[25]	U,u=[26]	r,u*	U,u*	U,u*	U	U	U	U	
14	Urea, $(NH_2)_2CO$	U,U*	U,u*	U,u*	U,u*	U,u*	U,u*	U,u=[27]	U	U,u=[28]	
15	Amino acids, $RCH(NH_2)COOH$	U,u*	r,rm,U*	r,U*	r,U*,s	U,u=[29]	r,u*	r,u*	R,U**	R,U**	R,U=u?[30]
16	Peptides, polypeptides	U,u*	U,u*	U,u*	r,u*,s	U,u*	U,u*	r,u*	U	U	U,U*
17	Proteins	U	U,u*	U	U,u*	U	U	r,u*	U,U*	U*	U,U*,s
18	Imidazole compounds	U	U,u*	U,u*	U,u*	U	U	U	U	U	U
19	Pyridioe compounds	U	U	r	r,u*	U	U	r	r	r	r
20	Pyrimidine compounds	U	U,u*,s	U,u*,	U,u*,s	r	r	r,u*	r	r	R
21	Purine compounds	U,u	rm,u*,s	U,u	U,u*,s	U	U	r,u*	U	U	U
22	Indole compounds	U,s	rm,u*	U	U,u*,s	U,s	U,s	U	U	U	U

/1/ U by virtue of symbiotic bacteria as in root nodules or legumes. /2/ Evidence for N_2 fixation conflicting. /3/ U by N_2 fixing bacteria. /4/ N_2 "fixation" by blue-green algae, Nostocaceae. U if H_2 or CO present. /5/ U by Phycomyces blakesleeanus, Mucorales. Probably U by all fungi. /6/ U in preference to NO_3^- by Chlorella. /7/ Dietary NH_4^+ U by ruminants; possibly others; NH_4^+ oxigioating as metabolic intermediate U in amino acid synthesis. /8/ U by tobacco plant. /9/ U by Clostridium pasteurianum, but not for growth; U for denitrification by Pseudomonas stutseri. /10/ Toxic to many plants, poorly U by tobacco plant. /11/ U as sole N-source by many fungi. /12/ U poorly by Chlorella pyrenoidosa. /13/ Acts as sole H acceptor in anaerobic metabolism of Aspergillus niger. R by some when mannitol is carbon source. Some R NO_3^- cannot substitute NH_4^+. /14/ U poorly by most yeasts. /15/ U by purple photosynthetic bacteria. /16/ Good N-source for tobacco plant. /17/ Good N-source for Aspergillus niger. /18/ U by Aspergillus niger when N-starved. /19/ Toxic. /20/ Cyanamide and derivatives U by many. /21/ Hydroxylamine poor N-source. /22/ Hydroxylamine U by Clostridium welchii, U in non-toxic concentration by Nitrosomonas. /23/ Hydroxylamine toxic. /24/ Glucosamine U. /25/ Acetamide U by some. /26/ Formamide and others U by Aspergillus, Both amino and amide N of asparagine U by Aspergillus. /27/ U by Astasia longa (colorless phytoflagellate). /28/ U by ruminants via rumen microflora. /29/ L-arginine, glutamine, cysteine, L-asparagine support more rapid growth of Chlorella than does NH_4^+.

181. NUTRIENTS: AMINO ACIDS, PEPTIDES, PROTEINS (SUMMARY)

R = Required by all forms studied; Ψ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; U = Utilized as a source of nitrogen and/or carbon by all forms studied although not a specific requirement for all; u = Utilized by one or more species or strains as a source of nitrogen and/or carbon although not a specific requirement; "u+" = Replaces effectively one or more other amino-acids, one of the interchangeable series being required in the diet; ϕ = Not utilized by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; * = Serves as complete nitrogen source for one or more species or strains; ** = Serves as simplest complete nitrogen source for one or more species or strains.

	Nutrient	Higher Green Plants[1]	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates[2]	Invertebrates: Protozoa[3]	Invertebrates: Insects	Vertebrates
1	Organic N (per se)	Ψ, u*	r, rm, u*[4]	r, rm, u*[4]	r, u*[4]	Ψ, u*	r, u*	r, U*	R, U*	R, U*
2	Proteins (per se)	Ψ	Ψ, u*	Ψ, u*	Ψ, u*	Ψ	u	r[5], u*	Ψ[6], s, U*	Ψ[6], s, U*
3	Polypeptides[7], peptones	Ψ, u*	Ψ, u*	Ψ, u*	r, u*[8]	Ψ, u*	u*[9], u*	r, u*	Ψ	Ψ, U
4	Amino acids	Ψ, u*[10]	r, rm, u*	rm, u*[11]	r[12], rm, u*	Ψ, u*[13]	r, u*[5], u*[14]	r[15], u*	R, U**	R, U**
5	Alanine	Ψ, u*	u*, u-[16]	u*	r, u*	Ψ, u*	Ψ, u*	u	r[17], u-	Ψ, U
6	Arginine	Ψ, u*	rm, u*	rm, u*	r, rm, u*	Ψ, u*	Ψ, u*	r[18], s, u	r[17], U	r[19], U
7	Aspartic acid[20]	Ψ, u*	u*, u-[16]	u*	r, u*	Ψ, u*	r, u*	u, s	r[17], u-	Ψ, U
8	Citrulline	Ψ	rm, u*		r, u*	Ψ		u	r, u-[21]	Ψ, u-[21], U
9	Cysteine	Ψ, u*	rm, u*	u*	r, u*	Ψ, u*		u	r, u-	Ψ, U
10	Cystine	Ψ, u*	rm, u*	u*	r, rm, u*	Ψ		u	r[17], u-	Ψ, U
11	Glutamic acid[20]	Ψ, u*	rm, u*[16], u*	u*	r, u*	Ψ, u*	Ψ, u*	u, s	r[22]	r[22], U
12	Glycine	Ψ, u*	rm, u*	u*	r, u*	Ψ, u*	Ψ, u*	r[18], u	r	r[23], U
13	Histidine	Ψ, u*	r, rm, u*	r, u*	r, rm, u*	Ψ, u*	r, u*	r[18], s, u	r[17]	R[24]
14	Isoleucine	Ψ, u*	rm, u*	rm, u*	r, rm, u*	Ψ, u*		r[18], u	r[17]	R[24]
15	Leucine	Ψ, u*	rm, u*	rm, u*	r, rm, u*	Ψ, ϕ	Ψ, u*	r[18], u	r[17], u-	R[24]
16	Lysine	Ψ, u*	rm, u*	u*	r, rm, u*	Ψ, ϕ	Ψ, u*	r[18], u	r[17]	R[24]
17	Methionine	Ψ, u	r, rm, u*	r, u*	r, rm, u*	Ψ, ϕ	r	r[18], u	r[17]	R[24, 25]
18	Phenylalanine	Ψ, u*	rm, u*	rm, u*	r, rm, u*	Ψ, ϕ	Ψ, u*	r[18], u	r[17], u-	R[24, 25]
19	Proline	Ψ, u*	rm, u*	u*	r, u*	Ψ, ϕ	Ψ, u*	r[18], u	r[17]	r, U
20	Serine	Ψ, u*	rm, u*	u*	r, u*	Ψ, ϕ	Ψ, u*	r[18], s, u	r[17]	R, U
21	Threonine	Ψ, u*	rm, u*	u*	r, u*	Ψ, ϕ		r[18], u	r[17], u-	R[24]
22	Tryptophan[26]	Ψ, u*	r, rm, u*	u*	r, rm, u*	Ψ, ϕ	Ψ, ϕ	r[18], u	r[17], s, u-	R[24]
23	Tyrosine	Ψ, u*	rm, u*	u*	r, rm, u*	Ψ	Ψ, ϕ	r[18], u	u-	R, U
24	Valine	Ψ, u*	rm, u*	u*	r, rm, u*	Ψ, u*	Ψ, u*	r[18], s, u	r[17], u-	R[24]

/1/ Spermatophytes (the intact plant). /2/ Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including colorless phytoflagellates. /4/ Most grow better on organic than on inorganic N. /5/ Many require living prey. /6/ On assumption that suitable amino acid combinations can replace complete proteins. /7/ See strepogenin (table 185). /8/ Entire peptides, polypeptides, low molecular weight proteins directly assimilated by some. /9/ Either 3 or 4 required by photosynthetic organisms growing in dark. /10/ Several tested intact plants grow on single amino acids as sole N-source. Growth attained on some amino acids is superior to that achieved with NH_4^+, NO_3^-, as N-source, on other amino acids inferior. Some plants grow less well on amino acids than on inorganic N. Marked differences exist between species with respect to amino acid utilization. Some amino acids are toxic, under the experimental conditions used, for some plants. Among plants tested are: tomato, tobacco, clover, pea, orchid embryos, young orchid. /11/ Amino acid mixtures superior to NH_4^+ as N-source for some, e. g. Saccharomyces cerevisiae, S. caribbergensis. /12/ Wide differences of requirement exist between species, species mutants, e. g. Leuconostoc mesenteroides R all the amino acids listed except 5 and 8, Lactobacillus bifidus R only 9. /13/ Based mainly on Chlorella pyrenoidosa. /14/ Marked differences between various species and varieties with respect to amino acid utilization; environmental conditions greatly modify. /15/ Best known requirement are those of Tetrahymena, Trichomonas foetus, Herpetomonas culicidarum, Glaucoma scintillans, /16/ Interchangeable for a Neurospora mutant. /17/ Basic common requirements of Tribolium confusum, Drosophila melnogaster, Aedes aegypti, Blattella germanica are covered by 6, 10, 13-18, 21, 22, 24. For A. aegypti 18 or 21 + 22 + 24 may be eliminated from diet. For B. germanica 5, 7, 11 u-, but one at least must be present; male also R 19, 20; 9, 10, 17 u-, and may be replaced by homocysteine, cysteic acid, isethionic acid, inorganic SO_4; 15, 24 u-; 18-23 u-, and may be replaced by 3, 4-dihydroxyphenylalanine, phenylacetic, 2, 4-dihydroxybenoic, shikimic, orsellinic acids. /18/ R by Tetrahymena geleii, Glaucoma scintillans, Trichomonas foetus, Herpetomonas culicidarum are 6, 13-18, 22, 24; in addition G. scintillans, T. foetus R 12, 19-21 and H. culicidarum R 23. T. geleii needs no other carbon source. /19/ R by rat, chicken. /20/ Asparagine (amide of ?) and glutamine (amide of 11) U by at least some in all the groups listed and R by some. /21/ 6, 8 interchangeable for some. /22/ R by chick. /23/ R by chick for rapid growth. /24/ R by man, mouse, rat, chicken. 13 not required to maintain nitrogen balance in adult human. /25/ Amount of methionine R by man depends on amount of cystine in diet. Amount of phenylalanine R by man depends on amount of tyrosine in diet. /26/ Precursor of niacin which it spares for some organisms.

182. NUTRIENTS: LIPIDS (SUMMARY)

Ψ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; "u+" = Utilized as effectively as a related substance by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

	Nutrients	Higher Green Plants[1]	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates[2]	Invertebrates: Protozoa[3]	Invertebrates: Insects	Vertebrates
					Steroids					
1	Cholesterol	Ψ	r[4]	u	u	Ψ	Ψ	r[5]	r	Ψ
2	7-Dehydrocholesterol	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ, u-[6]	u-	u[7]
3	Ergostanol acetate	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ, u-[6]		s[8]
4	Ergosterol	Ψ	R	u, s	Ψ	Ψ	Ψ	Ψ, u-[6]	u-	u[9]
5	Stigmasterol	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	u-	Ψ, s
					Long Chain Fatty Acids and Their Derivatives					
6	Arachidonic acid[10]	Ψ		Ψ		Ψ	Ψ		s	r, u-
7	Linoleic acid[10]	Ψ	rm	Ψ	s, i	Ψ	Ψ	u-[11]	r	r, u-
8	Linolenic acid[10]	Ψ		Ψ		Ψ	Ψ		u-	r, u-
9	Oleic acid	Ψ	rm, s	Ψ	s, i	Ψ	Ψ	s, i	r	Ψ
10	"Tween 80, 85"[12]	Ψ	Ψ	Ψ	Ψ, s, i	Ψ	Ψ	Ψ, s	Ψ	Ψ
11	"Myrj G 2144"[12]	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ, s	Ψ	Ψ
					Phospholipids					
12	Lecithin	Ψ	Ψ	Ψ	Ψ	Ψ	Ψ	s	u-, s	Ψ

/1/ Spermatophytes (the intact plant). /2/ Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including the colorless phytoflagellates. /4/ r by Labyrinthula vitellina (var. pacifica only). /5/ For several individual insect species various steroids u-. /6/ u- in place of 1 by Trichomonas. /7/ Precursor of vitamin D_3. /8/ Relieves "stiffness syndrome" of guinea pig. /9/ Precursor of vitamin D_2. /10/ The "essential fatty acids" of vertebrates. /11/ u + s required ether soluble factor of blood serum by Trichomonas. /12/ Synthetic detergents; "Tweens" = sorbitan esters of fatty acids, e. g. oleic; "Myrj G 2144" = polyoxalkalene derivative of oleic acid.

R = Required by all forms studied; ∄ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; "u=" = Utilized as effectively as the related compound(s) or vitamin by one or more species or strains; u> = Utilized more effectively than the related compound(s) or vitamin and considered to be required by one or more species or strains; u< = Utilized less effectively than the related vitamin by one or more species or strains; u>^e = Utilized as well or less effectively than the related vitamin by one or more species or strains; ∉ = Not utilized in place of the related vitamin by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

	Compound	Related Compound[2]	Higher Green Plants[3]	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagel-lates[4]	Invertebrates Protozoa[5]	Invertebrates Insects	Vertebrates
1	Vitamin A	(inc)A_1, A_2, A_3, (rel) 21A	∄, s	∄	∄	∄	∄	∄	r?	∄	R
2	Ascorbic acid		∄, s	∄, s	∄, s	r?, s	∄	r, s	∄	r	r
3	Biotin	(rel)20A, 24A, 30A, 34A	∄	r, rm, s	r, s	r	r	r, s	r	r	r
4	Choline group[6]		∄, s	r, rm	∄	r	∄	∄	r	r	r
5	Cobalamin[7]	(rel)39A, 45A	∄, s	∄	∄, s	r	r	r	r	r?, s	r
6	Vitamin D^9	(inc)D_2, D_3, D_4 etc.	∄	∄	∄	∄	∄	∄	∄	∄	R^9
7	Vitamin E	(inc)$\alpha, \beta, \gamma, \varepsilon$-Tocopherols	∄	∄	∄	∄	∄	∄	∄	∄, s	r
8	Inositol[10]	= meso-Inositol	∄, s	r, rm, s	r, s	r?, s	∄	∄	r	r	r
9	Vitamin K	$= K_1, K_2$	∄	∄	∄	r	∄	∄	∄	r	r
10	Nicotinic acid	(rel)11A, 25A, 48A	∄, s ?	r, rm, s	r	r, s	∄	∄	r	r	r
11	Nicotinamide	(rel)10A	∄, s ?	r, rm, s	u=	r, u=, s	∄	u=	u=	u=	u=
12	Pantothenic acid	(rel)19A, 22A, 31A, 35A	∄, s	r, rm, s	r	r, s	r	∄	r	r	R^9
13	Pteroylglutamic acid[11]	(rel)27A, 40A, 44A, 49A	∄	∄	∄	r^{12}	∄	∄	r	r	R
14	Pyridoxal[13]	(rel)15A, 16A, 41A, 42A	∄	u=	u=, s	r, u>	∄	∄	u=	u=	u=
15	Pyridoxamine[13]	(rel)14A, 16A, 41A, 42A	∄	u=	u=, s	r, u>	∄	∄	u=	u=	u=
16	Pyridoxine[13]	(rel)14A, 15A, 41A, 42A	∄, s	r, rm, s	r, s	r, s	∄, s	∄	r	r	R
17	Riboflavin		∄, s	∄	∄, s	r, s	∄	∄	r	r	R
18	Thiamine	(rel)26A, 32A; (co)43A+47A	∄, s	r, rm, s, i[14]	r, i[15]	r, s	r	r	r	r	R
19	β-Alanine	(po)12A	∄	rm, u=	∄, u=	u=	∄	∄, ∉	∄	∄, s	
20	Biocytin	(rel)3A	∄	∄	∄	u=	∄	∄	∄	∄	∄
21	β-Carotene[16, 17]	(pre)1A	∄	∄	∄	∄	∄	∄	∄	∄	∄, u<
22	Coenzyme A	(co)12A+ADP+PO_4	∄	∄	∄, s	r, u>	∄	∄	∄	∄	∄, u<
23	5, 6-Dimethylbenzimidazole	(po)5A	∄	∄	∄	∄	∄, u<	∄	∄	∄	∄, u<
24	Desthiobiotin	(rel)3A, 30A, 34A	∄	∄	∄	∄, u<	∄	∄	∄	∄	∄, u<
25	DPN[18]	(co)10A+ribose PO_4	∄	r, u>, s	∄, u=	r, u=	∄	∄	∄, u=<	∄, u=<	
26	Diphosphothiamine	(co)8A+PO_4	∄	∄, u<	∄, u=	r, u>	∄	∄, u=	∄, u	∄	∄, u=
27	Folic acid conjugates[19]	(co)13A+glutamate	∄	∄	∄, u=	∄, u=	∄	∄, u=	∄, u=	∄, u=	∄, u=
28	Folinic acid[20]	(rel)13A	∄	∄	∄	r	∄	∄, u=	∄	∄	∄, u<
29	Hesperidin[21]	(po) "Vitamin P" series	∄, s	∄	∄	∄	∄	∄	∄	∄	∄, s
30	O-Heterohistidin	(rel)3A, 24A, 34A	∄	∄	∄	∄, u<, ∉	∄	∄	∄	∄	∄
31	L. B. factor[22]	(rel)12A	∄	∄	∄	r, u>	∄	∄	∄	∄	∄
32	Lipothiamide	(co)18A+lipoic acid	∄	∄	∄	∄	∄	∄	∄	∄	∄
33	Lyxoflavin	(rel)17A	∄	∄	∄	∄, u<	∄	∄	∄	∄	∄, u<
34	Oxythiotin	(rel)3A, 24A, 30A	∄	∄	∄	∄, u<	∄	∄	∄	∄	∄
35	"Pantothenic acid conjugate"	(co)12A+adenine+glutamate	∄	∄	∄	r?, u>	∄	∄	∄	∄	∄
36	Pantoic acid	(po)12A	∄	∄	∄, u	∄, u	∄	∄	∄	∄	∄, ∉
37	Para-aminobenzoic acid	(po)40A	∄	r, rm	r	r	∄	r	∄	∄	∄, s
38	Pimelic acid	(rel po)3A	∄	∄, s	∄	∄, u=<	∄	∄, u<	∄	∄	∄, ∉
39	Pseudovitamin B_{12}	(rel)35A	∄	∄	∄	∄, u=	∄	∄, u=	∄	∄	∄, ∉
40	Pteroic acid	(po)13A	∄	∄	∄	∄, u<	∄	∄	∄, u=, ∉	∄	∄, ∉
41	Pyridoxal-PO_4	(rel)14A	∄	∄, u=	∄, u	r, u>	∄	∄	∄	∄, u=	∄, u=
42	Pyridoxamine-PO_4	(rel)14A	∄	∄, u=	∄, u	r, u>	∄	∄	∄, u=	∄, u=	∄, u=
43	Pyrimidine[23, 24]	(po)18A	∄	r, rm, $u^{23,24}$	r, s[23, 24]	r, u[23, 24]	r[23, 24]	r, u[23, 24]	∄, u[23, 24]	∄, u[23, 24]	∄, u=
44	Rhizopterin	(rel po)13A	∄	∄	∄	∄, u=	∄	∄	∄	∄	∄, ∉
45	α-Riboazole	(po)5A	∄	∄	∄	∄	∄	∄, u<	∄	∄	∄, s
46	Rutin[21]	(po) "Vitamin P" series	∄	∄	∄	∄	∄	∄	∄	∄	∄, s
47	Thiazole[24, 25]	(po)18A	∄	r, rm, $u^{24,25}$	r, $u^{24,25}$	r, $u^{24,25}$	r[24, 25]	r, u[24, 25]	∄, u[24, 25]	∄	∄
48	TPN	(co)10A+ribose+PO_4	∄	r, u>, s	∄, u=	r, u=	∄	∄	∄	∄	∄
49	Xanthopterin	(rel po)13A	∄	∄	∄	∄, u<	∄	∄	∄	∄	$r?^{26}$, $u>^{26}$, s

/1/ Vitamin = an organic compound, other than an amino-acid, carbohydrate or essential fatty acid, required in the diet by at least one vertebrate animal. /2/ (co) = composed of; (po) = part of, (pre) = precursor of; (rel) = related to; (inc) = includes. /3/ Spermatophytes (the intact plant). /4/ Green Phytoflagellates, chrysomonads, dinoflagellates. /5/ Including the colorless phytoflagellates. /6/ Includes: choline, betaine and other methyl donors./7/ Generic term including cyanocobalamin, hydroxocobalamin, vitamine B_{12}, B_{12a}, B_{12b}. /8/ For some, thymine desoxyriboside, hypoxanthine, adenine, guanine may substitute in certain media. /9/ D_2 active for mammals only; D_3 active for all and R by chicken. /10/ Of doubtful status as a vitamin. /11/ = Folic acid, folacin. /12/ For one or more, pteroic acid (q. v. 40A) or thymine + thymidine will substitute. /13/ Member of the pyridoxine group (Vitamin B_6). /14/ Inhibits growth of Rhizopus nigricans. /15/ Inhibits growth of strains of Saccharomyces cerevisiae. /16/ And other carotenoid precursors of Vitamin A. /17/ R? by certain crustacea. whose eyes contain vitamin A. /18/ Diphosphopyridine nucleotide. /19/ Di-, tri- and hepta-glutamates of pteroylglutamic acid. /20/ = The citrovorum factor, R by Leuconostoc citrovorum. /21/ 29, 46 and citrin = "vitamin P" series. /22/ Lactobacillus bulgaricus factor which = pantethein, pantethine, (N-(pantothenyl) β-amino-ethanol and corresponding di-sulfide?). /23/ Thiamine or pyrimidine moiety, (thiazole moiety is synthesized). /24/ Thiamine or pyrimidine + thiamine moieties, (pyrimidine and thiazole moieties combined to give thiamine). /25/ Thiamine or thiazole moiety. (pyrimidine moiety is synthesized). /26/ More active than pteroylglutamic (folic) acid in relieving anemia of Chinook salmon, (fish).

184. NUTRIENTS: PURINES, PYRIMIDINES (SUMMARY)

N = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; y = Not utilized by one or more species or strains; "u-" = Utilized as effectively as (or interchangeably with) one or more related compounds, the presence of at least one of the series being required by one or more species or strains. uc = Partially replaces or spares one or more required or interchangeably required compounds for one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

	Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Invertebrates: Protozoa	Invertebrates: Insects	Vertebrates
1	Pyrimidine compounds	N	r,rm,s	r,s	r,s,u	r	r	r,s	r	N,s
2	Purine compounds	N	rm,s,u	s,u	r,s,u	N	N	r,s	r	N,s
3	Cytidine	N	N,rm,s	N	u[1]	N	N	u-,i	N	N
4	Cytidylic acid	N	N,rm,s[2]	N	u[1]	N	N	u-,s	N	N
5	Cytosine	N	rm	N	u-[3]	N	N	r?,y[4],i	N	N
6	Orotic acid	N	rm,s[2]	N	r?,s	N	N	N,y[4]	N	N,s
7	Pyrimidine	(See table H16)								
8	Thymine	N	N	N	u-[5],uc[7]	N	N,uc[8]	r?,uc[9]	r	N,s
9	Thymidine	N	N	N	uc[7]	N	N	uc[9]	N	N,s
10	Uracil	N	rm,s[2]	N	u-[1],s	N	r?	r,uc[10]	r[11]	N
11	Uridine	N	N,rm,s	N	u-[1],s	N	N	u-	N	N
12	Uridylic acid	N	N,rm,s[2]	N	u-[1],s	N	N	u-	N	N
13	Adenine	N	rm	r-[12]	u-[13]	N	N,uc[8]	r?,uc[14]	r[11]	N,s
14	Adenosine	N	N	N	u-[13]	N	N	N,uc[14]	N	N
15	Adenosine triphosphate	N	N	N	u-[13]	N	N	N,s	N	N
16	Adenylic acid	N	N	N	u-[13]	N	N	r,uc[14]	N	N,s
17	Guanine	N	r,rm,s	N	u-[13],s	N	s	r[15]	r[11]	N
18	Guanosine	N	N	N	u-[13]	N	N	r?,u-,uc[16],i	N	N
19	Guanylic acid	N	N	N	u-[13]	N	N	u-,s	N	N
20	Hypoxanthine	N	r,rm	N	u-[13],s	N	s	u-,uc[14]	N	N
21	Xanthine	N	N	N	u-[12]	N	N	r?[17],y[4]	N	N
22	Others	N						r[18]		

/1/ At least one required, but interchangeable, for several species, e.g. Clostidium tetani, Hemophilus parainfluenzae. /2/ Stimulates mutants of Neurospora. /3/ Lactobacillus arabinosus, Leuconostoc mesenteroides r 5 or 17 (interchangeably). /4/ y by Tetrahymena. /5/ r by Lactobacillus bulgaricus 09. /6/ Clostridium tetani r either 13 or 20 (interchangeable). /7/ Spares folic acid for Streptococcus lactis; 8 + 9 replaces folic acid for B. lactis. /8/ Spares, and given with amino-acids, substitutes for para-aminobenzoic and folic acids for Euglena gracilis. /9/ Spares folic acid for Tetrahymena. /10/For Tetrahymena, 10 or 3, 4, 11 or 12 r. /11/ Drosophila melanogaster r 10 + sucrose, 10 + 13 + 17 or nucleic acid. /12/ r by Saccharomyces octosporus on certain media. /13/ Items 13-21 variously interchangeable for different bacteria, but at least one must be present, e.g. Streptococcus hemolyticus r at least one of 13, 14, 16, 17, 18, 19, 21 (the requirement is relieved by CO_2 in high concentration); 13, 17, 20 or 21 r Streptococcus lactis; 14 r by B. megaterium for spore germination. /14/ Spares but cannot replace 17, 18, 19, for Tetrahymena. /15/ r by Tetrahymena, replaceable by 18 or 19. /16/ Spares folic acid (as does adenosine) for Herpetomonas culicidarum. /17/ In vitro studies indicate a possibly requirement of 21 and also 5, 7, 10, 13, 18 by Plasmodium. /18/ Methyl purines e.g. theobromine, theophylline, caffeine s some ciliates and Suctoria.

185. NUTRIENTS: MISCELLANEOUS GROWTH FACTORS (SUMMARY)

R = Required by all forms studied; N = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; "u-" = Replaces effectively or utilized interchangeably with one or more other substances, but one of the interchangeable substances must be present; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

	Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Invertebrates: Protozoa	Invertebrates: Insects	Vertebrates
1	Adenylthiomethylpentose	N	N	N	N	N	N	N	N	N,s
2	Anthranilic acid	N	r,rm[1]	N	u-[1]	N	N	N	N	N,s
3	Antibiotics	N,s	N,s	N	r[2]	N	N	N,s	N	N,s
4	Asparagine	N	N	N,s,i	r[3]	N	N	N	N	N
5	"Bifidus" factor[4]	N	N	N	r	N	N	N	N	N
6	Carbon dioxide	R	r[5],s,i		r[5],s	R	R[6],s	r[7]	N	N
7	Carnitine	N	N	N	N	N	N	N	r[8]	N
8	Coprogen	N	r	N	N	N	N	N	N	N
9	N-D-Glucosylglycine ester	N	N	N	r	N	N	N	N	N
10	Glutamine	N	N,s,i	s,i	r[9],s	N	N	N	N	N
11	Glutathione	N	N	N	r[9]	N	N	N	s[10]	N
12	Guanidine	N	N	N	N	N	N	r,y[11]	N	N
13	Indole-3-acetic acid[12]	r?,s	r?,s	N	N,s	N,s	N,s[13]	N[13],i	N	N,s?
14	Hematin	N	r	N	r	N	N	r	r	N
15	Krebs cycle intermediates	N	r	N	r	N	r[14],s	N,s[14]	N	N,s
16	Mucin	N	N	N	r[15]	N	N	N	N	N,s
17	Mycobactin	N	N	N	r[16]	N	N	N	N	N
18	P-Hydroxybenzoic acid	N	rm	N	rm	N	N	N	N	N
19	Putrescine	N	rm	N	r,u-[17]	N	N	N	N	N
20	Quinic acid	N	rm	N	rm	N	N	N	u-[18]	N
21	Shikimic acid	N	rm	N	rm	N	N	N	u-[18]	N
22	Spermidine	N	N	N	r,u-[17]	N	N	N	N	N
23	Streptogenin	N	N,s?	N	r,rm,s	N	N	N	N	N,s?
24	Thioctic acid	N	N	N	r	N	N	r[19]	N	N
25	Unidentified factors		r		r					

/1/ Substitutes for tryptophan and/or indole. /2/ R by "dependent" mutants. /3/ R as growth factor and not replaceable by aspartic or glutamic acids. /4/ α- and β- Methyl-N-acetyl-d-glucosaminide? /5/ R by some in higher than atmospheric concentrations. /6/ R although another carbon source is available, particularly in darkness. /7/ R by some colorless phytoflagellates. /8/ R by Tenebrio molitor; interchangeable with γ-amino-β-hydroxybutryic acid. /9/ R by Neisseria gonorrhoeae. /10/ Favors larval growth of Drosophila and Aedes aegypti. /11/ Possibly R by Plasmodium in vitro; N by Tetrahymena. /12/ And related auxins. /13/ s Euglena gracilis (green phytoflagellate), ineffective for Astasia (colorless counterpart of Euglena). /14/ Several utilized for growth by the "acetate" flagellates; acetate utilized by most; wide variation among species with respect to utilization or availability of individual Krebs intermediates and related compounds such as pyruvate. /15/ Corynebacterium diphtheriae. /16/ Mycobacterium johnei. /17/ Interchangeable with spermidine for some. /18/ Spares or replaces phenylalanine, tyrosine for Blatella germanica. /19/ R by Tetrahymena geleii (8 strains), T. vorax (2 strains); spared but not replaced by acetate; R? by Perunema trichophorum.

A sulfur source is required by organisms in all categories listed below.

R = Required by all forms studied; R = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; U = Utilized by all forms studied; U = Not utilized by any forms studied; u = Utilized by one or more species or strains.

	Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Invertebrates		Vertebrates
								Protozoa[1]	Insects	
	Inorganic Sulfur Sources									
1	Sulfur[2] (elemental), S	R, U	u[3]	u	r[4]	R, U	R	R	R	R, u[5]
2	Sulfhydryl, (SH)	R	u			R	R	R	R	R
3	Sulfide, (S)	R	u[6]		u[7]	R, u[8]	R	R	R	R, U
4	Bisulfite, (HSO_3)	R	u[9]			R	R	R	R	R, U
5	Sulfite, (SO_3)	R, u	u[9]		u[10]	R	R	R	R	R, U
6	Sulfate, (SO_4)	U	u[9]	u	r	U	U	r	R	R, u[11]
7	Thiosulfate, (S_2O_3)	R, u	rm, u		u[12]	R	R	R	R	R, U
8	(S_2O_8)[13]	R	u?			R	R	R	R	R
9	Tetrathionate, (S_4O_6)	R			u	R	R	R	R	R
10	Sulfoxylate, (SOOH)	R	u[14]		u	R	R	R	R	R
11	(SO) as Sulfur hydrate, H_2SO	R			u	R	R	R	R	R
12	Thiocyanate, (SCN)	R	u		u[15]	R	R	R	R	R
13	Persulfate	R	u[9]			R	R	R	R	R
	Sulfur Containing Amino Acids, Sulfoproteins[16]									
14	Cystathionine	R	u		u	R	R	R, u	u	u
15	Cysteine	R, u	u[6]	u	r	R, u[17]	R, u	u	u[18]	U
16	Cystine	R, u	u[6]	u	r	R	R, u	u	u	U
17	Homocysteine	R	U		u	R	R	R, u	u	u
18	Homocystine	R	U		u	R	R	R, u	u	u
19	Methionine	R, u	U	u	r	R, U	r	r[19]	R	
20	Peptones	R, u	U	u	u	R, u	R	r	u	R, U
	Sulfur Containing Vitamins and Growth Factors[16]									
21	Biotin [20]	R	u	u	u	R	r	r?	R	R?, U
22	Coenzyme A	R	R	R	R	R	R	R	R	R, U
23	Glutathione ($^{14}G-SH^{21}$)	R	u	u	r	R	u	R, u	r	R, U
24	Thiamine[22]	R	U	r	r	u	r	r	r	R
25	Thiazole[22]	R	u	r[24]	r[24]	r	r[24]	r-24, u	R	R
26	Thioctic acid[25]	R	R	R	r[26]	R	R	r[27]	R	R
	Miscellaneous Sulfur Compounds									
27	Alkylsulfides, R-S-S-R	R		u[28]		R	R	R	R	R
28	Alkylsulfinates, R-SO_2-R	R	u			R	R	R	R	R
29	Alkylsulfonates, R-SO_3-R	R	u			R	R	R	R	R
30	Dithionate	R	u[29]			R	R	R	R	R
31	Ethereal sulfates	R	U			R	R	R	R	R
32	Sulfamate, (SO_3-NH_2)	R	u			R	R	R	R	R
33	Sulfonic acid amides	R	rm		R	R	R	R	R	R
34	Sulfoxides, R_2SO	R	u		u	R	R	R	R	R
35	Taurine	R	u		R	R	R	R	R	R
36	Thioacetamide	R	u		u	R	R	R	R	R
37	Thioacetate	R	r, u[6]		u?[30]	R	R	R	R	R
38	Thiocarbonate	R	r, u[6]			R	R	R	R	R
39	Thioglycolate	R	r, u[6]		u?[31]	R	R	R	R	R
40	Thiols, R-SH	R	u			R	R	R	R	R
41	Thiooxalate	R	u			R	R	R	R	R
42	Thiourea	R	u[6]	u[32]	u?[33]	R	R	R	R	R

/1/ Including the colorless phytoflagellates. /2/ The substance not in combination with other elements. /3/ U by Fusarium lini. /4/ U by Thiobacillus thio-oxidans, Sporovibrio desulfuricans, S. aestuarii, Thiorhodaceae. /5/ Bacteria, in ruminants, build the element into amino acids (methionine; cystine). /6/ Some aquatic fungi, e. g., members of the Blastocladiales and Saprolegniales, U oxidized sulfur; these require a reduced sulfur source, e. g., H_2S, cysteine, cystine, methionine, thioacetate, thiocarbonate, thioglycolate, thiourea. /7/ U, e. g., by Beggiatoa, Thiothrix, Thiopiocs, Thiobacilli. /8/ Synechococcus, grown in an atmosphere of N_2, U N_2S (with reduction of CO_2); Oscillaria and Finnularia also reduce CO_2 with H_2S, depositing S in their cells, Scenedesmus also U sulfide, H_2S toxic to-Chlorella. /9/ U by Brevilegnea gracilis; U by many other Saprolegniaceae. /10/ U by Sporovibrio desulfuricans, S. aestuarii. /11/ U for formation of chondroitin sulfate and heparin; U by laying hen by conversion to cystine. /12/ U by Thiobacillus novellus, Pseudomonas aeruginosa, P. fluorescens, Achromobacter stutseri, others. /13/ Decomposes on contact with H_2O. /14/ Inorganic sulfur, less oxidized than sulfinate, not efficiently U by Aspergillus niger. /15/ NH_4SCN can be U by Bacillus thiocyan-oxidans as sole source of C, N, and S. /16/ R, r, U, u, may mean as a sulfur source, or the compound may be R for its molecular structure, not synthesized by the organism. /17/ U as N-source (and sulfur source?) by Chlorella pyrenoidosa. /18/ Also U cystetic acid, isethionic acid. /19/ Also U methionine sulfoxide, taurine. /20/ Biotin R by numerous fungi, yeasts, bacteria and by most of the vertebrates and invertebrates studied. The replacement of S in the biotin molecule does not affect the activity for some bacteria. /21/ Complex of cysteine, glycine, and glutamic acid. /22/ Thiamine, containing pyrimidine and thiazole (the latter an imidazole ring with one C replaced by sulfur), is R by numerous organisms; probably also a sulfur source? /23/ U as sulfur source by Aspergillus niger (cannot rupture the thiazole ring?). /24/ Satisfies thiamine requirement for some (cf. Fn 22); probably a sulfur source? /25/ = Protogen, or α-lipoic acid. /26/ R by Streptococcus fecalis for oxidation of pyruvate. /27/ R by Tetrahymena geleii (8 strains), T. vorax (2 strains). /28/ U by Scopulariopsis (Penicillium brevicaulis, Schizophyllum commune). /29/ U by Saprolegniaceae. /30/ U as carbon source by many; improbable sulfur source. /31/ Surface active in culture media for many fastidious forms; powerful reducing agent; U as carbon source; improbable as sulfur source. /32/ U by Torula monosa, T. dattila. /33/ U as nitrogen source by many bacteria; probable sulfur source?

187. DIETS, LOW AND MODERATE COST: MAN, U. S. A.

These food plans (low cost=L; moderate cost=M) represent quantities per week, as purchased, that will furnish nutritionally adequate diets as judged by the National Research Council's recommended allowances (1948). Both the low and moderate cost plans have the same adjustment for losses of vitamins in cooking. Values are in kilograms, except for milk (litres) and eggs (number).

	Family Members	Leafy, Green and Yellow Vegetables kg		Citrus Fruit, Tomatoes kg		Potatoes, Sweet-potatoes kg		Other Vegetables and Fruit kg		Milk[1] L		Meat, Poultry, Fish kg		Eggs no.		Dry Beans and Peas, Nuts kg		Flour, Cereals[2] kg		Fats and Oils[3] kg		Sugar, Sirups, Preserves kg	
		L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
	Children																						
1	9–12 mo	0.68	0.68	0.79	0.79	0.23	0.23	0.45	0.45	5.68	5.68	0.11	0.11	5	5	0.03	0.03	0.28	0.28	0.03	0.03	0.03	0.03
2	1–3 yr	0.79	0.91	0.79	0.91	0.45	0.23	0.45	0.79	5.20	5.68	0.23	0.34	5	6	0.03	0.03	0.57	0.57	0.06	0.06	0.06	0.06
3	4–6 yr	0.79	1.02	0.79	1.02	0.68	0.45	0.57	1.02	5.20	5.68	0.45	0.57	5	7	0.06	0.03	0.79	0.68	0.17	0.17	0.17	0.23
4	7–9 yr	0.91	1.13	0.91	1.13	1.13	0.79	0.68	1.13	5.20	6.15	0.68	0.79	5	7	0.11	0.06	1.02	0.91	0.23	0.23	0.28	0.34
5	10–12 yr	1.02	1.36	1.02	1.25	1.36	1.02	0.79	1.13	5.68	6.62	0.79	1.02	5	7	0.11	0.06	1.47	1.25	0.34	0.34	0.34	0.40
	Girls																						
6	13–15 yr	1.02	1.59	1.02	1.25	1.47	1.13	0.79	1.59	6.15	6.62	0.91	1.25	5	7	0.11	0.06	1.59	1.25	0.34	0.40	0.34	0.40
7	16–20 yr	1.02	1.59	1.02	1.25	1.36	1.13	0.79	1.59	4.73	5.68	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.34	0.28	0.40
	Boys																						
8	13–15 yr	1.13	1.59	1.13	1.36	1.81	1.59	1.02	1.59	6.15	6.62	0.91	1.36	5	7	0.23	0.11	2.04	1.81	0.45	0.51	0.40	0.51
9	16–20 yr	1.25	1.81	1.13	1.59	2.27	2.04	1.13	1.59	6.15	6.62	0.91	1.47	5	7	0.23	0.17	2.61	2.38	0.62	0.62	0.45	0.57
	Women																						
10	Sedentary	1.02	1.47	0.91	1.13	1.02	0.79	0.79	1.47	4.73	4.73	0.91	1.13	5	7	0.11	0.03	0.91	0.79	0.28	0.28	0.28	0.34
11	Mod. active	1.02	1.59	0.91	1.13	1.36	1.13	0.79	1.59	4.73	4.73	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.40	0.34	0.40
12	Very active	1.13	1.70	1.13	1.36	1.81	1.47	0.91	1.81	4.73	4.73	0.91	1.36	5	7	0.17	0.11	1.93	1.70	0.45	0.51	0.45	0.51
13	Pregnant	1.36	1.81	1.13	1.59	1.13	1.02	0.91	1.36	7.10	7.10	1.02	1.36	7	7	0.11	0.06	1.13	1.02	0.28	0.28	0.23	0.28
14	Nursing	1.59	1.81	1.70	2.04	1.81	1.36	1.02	1.59	9.94	9.94	1.13	1.36	7	7	0.11	0.06	1.36	1.13	0.28	0.34	0.23	0.34
15	60 yr or over	1.13	1.59	1.02	1.25	1.13	0.91	0.79	1.36	4.73	5.20	0.91	1.13	4	6	0.06	0.03	1.02	0.79	0.23	0.23	0.23	0.28
	Men																						
16	Sedentary	1.02	1.59	0.91	1.13	1.36	1.13	0.79	1.59	4.73	4.73	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.40	0.34	0.40
17	Phys. active	1.13	1.70	1.13	1.36	1.81	1.47	0.91	1.81	4.73	4.73	0.91	1.36	5	7	0.17	0.11	1.93	1.70	0.45	0.51	0.45	0.51
18	Heavy work	1.13	1.81	1.13	1.59	2.72	2.27	1.13	1.93	4.73	4.73	0.91	1.59	5	7	0.28	0.17	3.52	3.18	0.85	0.91	0.45	0.57
19	60 yr or over	1.13	1.59	1.02	1.25	1.47	1.25	0.79	1.36	4.73	5.20	0.91	1.25	4	6	0.06	0.06	1.47	1.13	0.28	0.34	0.28	0.34

/1/ Or its equivalent in cheese, evaporated milk, or dried milk. /2/ Count 0.68 kg bread as 0.45 kg flour. /3/ For small children, and pregnant and nursing women, cod-liver oil or some other source of vitamin D is also needed. For elderly persons and those who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable. /4/ To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

188. DIETS: LABORATORY AND DOMESTIC ANIMALS

These diets have been selected from a large number of possible diets. They are not necessarily optimal, nor do they suit all conditions and feeding purposes. Consult texts on feeding for more detailed information. Unless otherwise indicated, values are grams per 100 grams of ration, the daily food or feed intake is expressed as kg per animal, and the values are for adult animals.

	Animal	Intake[1], kg	Diet
1	Cattle, beef[2], 408 kg	I-9, 4; II-9, 0; III-17. 9	Diet I: alfalfa hay, 20; oat hay, 80. Diet II: corn fodder, 50; barley straw, 25; alfalfa hay, 25. Diet III: corn silage, 69; oat straw, 27; cottonseed meal (41% protein), 4.
2	Chicken, Rhode Island Red[3], 2. 5 kg	0.092	Corn, ground yellow, 49; standard wheat middlings, 15; wheat bran, 10; alfalfa meal, 5 (meal contains 75,000 or more I. U. of vitamin A per lb); soybean oil meal, 4; fish meal, 4; meat meal, 4; dried whey, 4; steamed bone meal, 1; ground limestone, 3. 5; salt, 0. 5; vitamin A and D feeding oil (300 International Chick Units vitamin D, 1500 I. U. vitamin A, per gram), 0. 3; anhydrous $MnSO_4$, 0. 0125 g, and riboflavine 0. 1 mg per 100 g feed.
3	Dog[4]	Varies with breed	Meat, meat by-products including bone, or fish, 20; soybean meal, wheat germ, corn germ, or nut meal, 20; corn, wheat, or barley, 50; carrots, beet by-products, or tomato by-products, 2-5; iodised salt, 0. 24-0. 5; milk, liver meale, or fermentation residues, q. s.; fish liver oils and irradiated yeast, q. s.
4	Fish[5], 0. 002-0. 05 kg	0. 04-3 at 10^0C	Diet I: pork or beef spleen, 35; beef liver, 15; salt, 2; fish meal, 12; wheat middlings, 12; dried skim milk or distillers' solubles, 12; cottonseed meal, 12. Diet II: beef liver, 33; beef spleen, 33; horse meat, 34.
5	Horse[6], 544 kg	11. 6	Diet III: spoked carp or other rough fish, 45; oatmeal, 5; beef liver, 15; beef or pork spleen, 35. Timothy hay, 26; alfalfa hay, 20; oats, 32; corn, 22.
6	Monkey[7], 1. 5-3 kg	0. 06-0. 12	Sucrose, 71; "de-vitaminized" casein, 18; corn oil, 4; salt mixture, 3 (composed of $CaCO_3$, 300 g; K_2HPO_4, 470 g; $CaHPO_4$, 680 g; $MgSO_4$, 100 g; NaCl, 670 g; KCl, 115 g; $FeC_6H_5O_7$, 55 g; KI, 1. 6 g; $MnSO_4 \cdot H_2O$, 5 g; $ZnCl_2$, 4 g; $CuSO_4$, 2. 4 g; $CoCl_2$, 0. 2 g); whole liver substance, 2; liver concentrate powder, 2. To each 18 g of casein, add: thiamine hydrochloride, 350 µg; pyridoxine hydrochloride, 350 µg; nicotinamide, 2. 5 mg; choline chloride, 100 mg; inositol, 100 mg; para-aminobenoic acid, 30 mg; calcium pantothenate, 2 mg; riboflavin, 350 µg; folacin, 200 µg; biotin, 20 µg; ascorbic acid, 10 mg. To each 4 g of corn oil, add: 90% β-carotene, 90 µg; calciferol, 0. 8 µg; α-tocopherol, 5 mg; menadione, 100 µg.
7	Rat[8], 0. 18 kg	0. 007	Casein, 35; corn starch 37; lard, 15; butter fat, 9; salt mixture, 4 (composed of $CaCO_3$, 134. 8 g; Na_2CO_3, 34. 2 g; $MgCO_3$, 24. 2 g; K_2CO_3, 141. 3 g; H_3PO_4, 103. 2 g; HCl, 53 g; H_2SO_4, 9. 2 g; citric acid-H_2O, 111 g; Fe citrate-$4H_2O$, 6. 3 g; KI, 0. 02 g; $MnSO_4$, 0. 079 g; NaF, 0. 248 g; $K_2Al_2(SO_4)_4$, 0. 0245 g). To this ration, add 0. 5 g yeast, 25 g lettuce.
8	Sheep[9], 32 kg	I-3. 8; II-1. 2; III-1. 5	Diet I: barley (corn, oats, or sorghum), 10. 1; beet pulp, wet, 70; alfalfa hay, 20. Diet II: corn (barley or wheat), 42; alfalfa, 58. Diet III: corn, 32; soybean oil meal, 5. 9; alfalfa hay, 32; corn silage, 30.
9	Swine[10], 45 kg	I, II, III, IV, or V-2. 4	Diet I: corn (yellow), 63; oats, 15; soybean meal, 7. 8; middlings, 5. 0; meat scrap, 3. 0; alfalfa meal (dehydrated), 5. 0; limestone, 0. 7; salt, 0. 5. Diet II: barley, 50; oats, 40; linseed meal, 3. 0; fish meal, 1. 0; meat scrap, 3. 0; minerals (sodium salt, 20%; steamed bonemeal, 37. 7%; ground limestone, 40%; ferrous sulfate, 2%; manganese sulfate, 0. 2%; copper sulfate, 0. 1%), 3. 0; A and D oil (to supply 45,000 I. U. vitamin A and 9,000 I. U. vitamin D per 45 kg of feed). Diet III: barley, 83; tankage, 3; soybean meal, 8; alfalfa meal (deh.), 4. 5; bone meal, 0. 5; limestone, 0. 5; salt, 0. 5. Diet IV: corn, 82; soybean meal, 6. 5; meat and bone scrap, 2. 5; fish meal, 2. 5; cottonseed meal, 2. 5; alfalfa meal (deh.), 2. 5; limestone, 0. 5; bone meal, 0. 5; salt, 0. 5. Diet V: corn, 79; soybean meal (solvent extracted), 13. 5; alfalfa meal (sun cured), 5. 0; mineral mix (same as Diet II), 2. 0; vitamin mix (each lb contains riboflavin, 200 mg; pantothenic acid, 500 mg; B_{12}, 2 mg; and an antibiotic in an amount suited to its kind)

/1/ The numerals I, II, etc., refer to alternative dietary mixtures given in column C. /2/ Wintering pregnant cow. /3/ Mature, breeding. /4/ For more detailed diets, see Report of Committee on Animal Nutrition, National Research Council, 8, Dec. 1953. /5/ Brook, brown and rainbow trout, age 3-9 months. /6/ Lactating mare. /7/ Rhesus, juvenile. /8/ White, age 1-6 months. /9/ Fattening lambs. /10/ About 1/4 grown.

Diets illustrate the feeding practices successfully in use in the New York, Chicago, and San Diego zoological parks. Differences in diet reflect climatic conditions, food availability, and individual variation within species. Body weights and feed values are estimates and are for a single animal of the species listed.

	Species	Zoo[1]	Sex	Body Weight lb	Total Feed[2] lb/wk	Composition of Diet: Horse Meat lb/wk	Liver, Kidney lb/wk	Miscellaneous lb/wk[3]
	Monotremata							
1	Platypus (Ornithorhynchus anatinus)	NY	M	3.3				Earthworms, 7; crayfish (105-140); mealworms (1400); frogs (14); eggs (14).
	Marsupialia							
2	Kangaroo, red (Macropus rufus)	SD	M	54	57			Alfalfa, 21; apples, 7; bread, 5; lettuce, 21; browse, 3.
3		NY	M	130	49.1			Rolled oats, 5.3; apples, 3.5; bananas, 1.8; bread, 3.5; cabbage, 2.1; carrots, 3.5; crushed oats, 1.4; clover hay, 21; lettuce, 3.5; white potatoes, 3.5.
4	Wombat (Vombatus hirsutus)	NY	F	20	10.3			Rolled oats, 1; apples, 3.5; bananas, 0.7; bread, 2.1; carrots, 1; crushed oats, 1; white potatoes, 1.
	Primates							
5	Gorilla, lowland (Gorilla gorilla)	NY	F	296	53.9+	2.3		Powdered whole milk, 1; cereal, 1; malted milk powder, 0.2; honey, 42 g; eggs, 1.4; sugar, 0.6; dicalcium phosphate, 14 g; carrots, 17; celery, 3.5; bananas, 7; oranges, 2.7; apples, 5.4; cabbage, 1.8; lettuce, 2.3; grapes, 2.3; sweet potatoes, 2.3; green beans, 2.3; spinach, 0.5; scallions, 0.3; vitamins, 12 drops.[4]
6	Mandrill (Mandrillus sphinx)	SD	M	25	25.6			Apples, 5.3; bread, 0.8; fruit, 5.3; sweet potatoes, 0.1; lettuce, 5.6; onions, 0.5; corn, 2; tomatoes, 3.5; avocados, 1.5; string beans, 1.
7	Orangutan (Pongo pygmaeus)	NY	M	105	31.5+	7.0		Apples, 3.5; bananas, 5.3; bread, 0.8; cabbage, 1.8; carrots, 8.8; eggs (14); grapes, 0.8; lettuce, 3.5; dog biscuit[5], (28); milk mixture[6], 7 gal.
8		SD	M	150	60.6	1.8		Bread, 2.1; fruit, 10.5; string beans 2.3; tomatoes, 10.5; lettuce, 8.8; sweet corn, 1.5; bananas, 1.8; sweet potatoes, 3.9; grapes, 1.5; milk, 0.5; peanuts, 0.8; avocados, 3.0; rice & raisins, 1.
	Carnivora							
9	Badger, Canadian (Taxidea taxus)	SD		30	6			Dog food mix[7], 6.
10	Bear, Eurasian brown (Ursus arctos)	SD	M	450	72+	15		Mackerel, 21; eggs (24); lettuce, 1.5; apples, 1.5; fruit, 3; bran & honey[8], 3; celery, 9; bread, 12; tomatoes, 1.5; avocados[9], 4.5.
11	Bear, grizzly (Ursus horribilis)	SD	M	700	85.5+	24		Mackerel, 12; eggs (24); lettuce, 3; apples, 3; fruit, 4.5; bran & honey[8], 6; celery, 13.5; bread, 12; tomatoes, 1.5; avocados[9], 6.
12	Bear, kodiak (U. middendorfii)	NY	M	800	132-150	42		Butterfish, 30; mackerel, 30; apples, 18; bread[10], 12.
13	Bear, polar (Thalarctos maritimus)	SD	F	300	76.5+	24		Mackerel, 2.4; eggs(36); apples, 3.6; fruit, 9; bran & honey[8], 9; celery, 13.5; bread, 9; tomatoes, 1.5; avocados, 4.5.
14	Bear, sloth (Melursus ursinus)	SD	F	350	13.5-15	4.5		Eggs (24); lettuce, 1.5; fruit, 3; bran & honey[8], 3; avocados[11], 3.
15	Cheetah (Acinonyx jubatus)	SD	M	120	38	35	1	Jungle fowl, rabbit, or guinea pig, 2.
16	Dingo (Canis dingo)	SD	M	50	25+	2.5	1	Dog food mix[7], 12.5; jungle fowl, rabbit, or guinea pig, 2; milk, 7; eggs (12).
17	Fox, Arctic (Alopex lagopus ungava)	SD		15	6			Dog food mix[7], 6.
18	Hyena, spotted (Crocuta crocuta)	SD	M	100	18	15	1	Jungle fowl, rabbit, or guinea pig, 2.
19	Jaguar (Panthera onca)	SD	M	175	33	30	1	Jungle fowl, rabbit, or guinea pig, 2.
20		NY	M	175	39.5+	34	5	Bone meal, 0.5; cod-liver oil, 48 ml.
21		LP	M		18+	18		Vitamin and mineral supplement.
22	Leopard (Panthera pardus)	SD	M	120	33	30	1	Jungle fowl, rabbit, or guinea pig, 2.
23		NY	F	125	22.7+	21.5	1	Bone meal, 0.2; cod-liver oil, 30 ml.
24		LP	M		9+	9		Vitamin supplement.
25	Lion (Panthera leo)	SD	M	250	75	72	1	Jungle fowl, rabbit, or guinea pig, 2.
26		NY	M	350	57.5+	55	2	Bone meal, 0.5; cod-liver oil, 57 ml.
27		LP	F		45+	45		Vitamin and mineral supplement.
28	Lynx, Yukon (Felis canadensis mollipilosus)	SD		35	14.4+	12		Eggs (6); milk, 2.4.
29	Ocelot (Felis pardalis)	SD		16	12	10	2	
30	Panda, lesser (Ailurus fulgens)	SD		14	18+			Milk, 3.5; eggs (14); apples, 1.75; fruit, 1.75; dates, 1.75; raisins, 0.4; grapes, 1.75; bananas, 7; Pablum, 0.1; fresh bamboo, ad lib.
31	Raccoon (Procyon lotor)	LP			4.8	3.6		Whole wheat bread, 1.2.
32	Tiger, Bengal (Panthera tigris)	SD	M	350	87	84	1	Jungle fowl, rabbit, or guinea pig, 2.
33	Wolf, N. American (Canis lupus nubilis)	SD	M	80	33	5	1	Dog food mix[7], 25; jungle fowl, rabbit, or guinea pig, 2.
	Pinnipedia							
34	Sea lion (Zalophus californianus)	NY	M	600	96			Butterfish, 48; mackerel, 24; smelts, 24.
35	Seal, harbor (Phoca vitulina geronimensis)	NY	F	70	28			Mackerel, 28.
	Rodentia							
36	Chinchilla	LP		1.25	9 oz			Rabbit chow (Purina), 1.1 oz; timothy hay, 2.7 oz; carrots, 1.8 oz; rolled oats, 0.4 oz; yellow corn, 0.4 oz; wheat germ, 0.05 oz; flax seed, 0.1 oz; $CaHPO_4$, 0.1 oz; raisins, 0.03 oz; oyster shells, 0.1 oz; apple bark, 0.2 oz.

	Proboscides							
37	Elephant, Indian (Elephas maximus)	SD	F	4500	879			Grain mix[12], 28; avocados[13], 15; celery, 70; apples, 35; oat hay, 630; bread, 14; sweet corn[14], 105.
38		NY	F	5500	846-966			Alfalfa[15], 350; timothy[15], 490; GLF[16], 42; crushed oats, 38.5; bread, 15; cabbage, 15; potatoes, 15.
39		LP	F					Apples (168); rye or whole wheat bread, 42; carrots, 168 qt; beets, 1.6 bu; timothy, 560; alfalfa, 28; oats, 7 pk; bran, 7 pk; cornstalks.
	Artiodactyla							
40	Alpaca (Lama pacos)	SD	M	200	45			Alfalfa pellets[17], 14; grain mix[12], 6; avocados[13], 6; lettuce, 3; carrots, 9; browse, 7.
41	Antelope, sable (Hippotragus niger roosevelti)	SD	M	550	86			Alfalfa pellets[17], 49; grain mix[12], 6; avocados, 6; carrots, 6; celery, 9; browse, 10.
42	Buffalo, African (Syncerus caffer)	SD	M	1600	402a			Alfalfa pellets[17], 350; grain mix[12], 12; avocados[13], 15; browse, 25 (occasionally).
43		NY[18]	M	1400	252.8a			Clover, 140; GLF[16], 26.3; crushed oats, 24.5; cabbage, 51.5; lettuce, 10.5; green leaves 1 or 2 x/wk.
44	Camel, dromedary (Camelus dromedarius)	NY[18]	F	1310	140			Clover, 105; GLF[16], 35.
45	Deer, red (Cervus elaphus)	SD	F	350	93			Alfalfa pellets[17], 35; grain mix[12], 6; avocados, 6; carrots, 6; celery, 30; browse, 10.
46	Giraffe, uganda (Giraffa camelopardalis rothschildi)	SD	M	2500	622.9			Alfalfa pellets[17], 105; grain mix[12], 45; carrots, 60; apples, 90; potatoes, 42; onions, 35; tea, 0.9; acacia browse, 245.
47		NY[18]	F	1300	254.3			Clover, 140; GLF[16], 31.5; crushed oats, 31.5; apples, 2.3; bananas, 14; bread, 21; cabbage, 3.5; white potatoes, 5.6; carrots, 3.5; lettuce, 1.4.
48	Hippopotamus (Hippopotamus amphibius)	SD	M	4000	693			Alfalfa pellets[17], 420; grain mix, 18; avocados, 15; lettuce, 60; celery, 60; sweet corn, 120.
49	Llama (Lama glama)	SD	M	275	90			Alfalfa pellets[17], 35; grain mix, 6; avocados, 9; carrots, 30; browse, 10.
50		NY[18]	M	285	59.5			Clover, 38.5; GLF[16], 14; crushed oats, 7.
51	Moose (Alces americana)	SD	M	750	609			Grain mix[12], 91; avocados, 21; lettuce, 42; carrots, 60; apples, 150; browse, 245.
	Perissodactyla							
52	Rhinoceros, black (Rhinoceros bicornis)	NY	M	2800	615.5			Alfalfa[15], 140; timothy[15], 210; GLF[16], 10.5; bread, 210; cabbage, 15; carrots, 15; potatoes, 15.
53	Zebra, Chapman (Equus burchelli antiquorum)	SD	M	600	124			Alfalfa pellets[17], 7; grain mix[12], 6; carrots, 6; oat hay, 105.
54		NY	F	650	90.3			Timothy, 70; crushed oats, 16.8; carrots, 3.5.
	Struthioniformes							
55	Ostrich, N. African (Struthio camelus)	SD	M	250	28.8a	7		Bread, 5.3; lettuce, 6; alfalfa, 3.5; barley, 7; oyster shell.
	Casuariiformes							
56	Cassowary (Casuarius unappendiculatus occipitalis)	SD	F	100	45.6+	1.8		Apples, 14; bananas, 7; mice (28); fruit, 14; tomatoes, 8.8.
57	Emu (Dromicelus novaehollandiae)	SD	M	100	29.8	1.8		Bread, 5.2; lettuce, 7; barley, 7; apples, 8.8.
58		NY		60	22.1+	1.3		Apples, 3.5; bread, 7; lettuce, 5.2; rolled oats, 2.5; GLF[16], 2.6; whole corn, 7 pt in winter; scratch, 7 pt in summer.
	Sphenisciformes							
59	Penguin, king (Aptenodytes p. patagonica)	NY		45	24.5a[19]			Mackerel, 24.5.
	Pelecaniformes							
60	Pelican, European white (Pelecanus occidentalis onocrotalus)	SD		15	17.5			Anchovies & sardines, 17.5.
61		NY		14	15.6a[20]			Butterfish[21], 15.6.
	Ciconiiformes							
62	Heron, cocoi (Ardea cocoi)	NY		5	3			Butterfish, 3.
63	Shoebill (Balaeniceps rex)	SD	F	12	16			Anchovies & sardines, 7; liver, 9.
64		NY		16	12.5			Butterfish, 12.5.
	Falconiformes							
65	Condor, Andean (Vultur gryphus)	SD		50	14			Anchovies & sardines, 14.
66		NY		22	10	10a		Rats (2) instead of horse meat 2 x/mo.
67	Eagle, bald (Haliaeetus leucocephalus)	SD		6	3.5			Anchovies & sardines, 3.5.
68		NY		12	5.8	3.8		Butterfish, 2.
	Strigiformes							
69	Owl, snowy (Nyctea scandinaca)	SD		3	2.5+			Anchovies & sardines, 2.5.
70		NY		3	2.5	2.5		Rat (1).
	Micropodiformes							
71	Hummingbird, ruby-throated (Archilochus colubris)	NY		2.5 g	122 ml			Mellin's formula[22], 112 ml; honey formula[23], 9.8 ml.

/1/ NY=New York Zoological Park, New York, N.Y.; SD=San Diego Zoological Gardens, San Diego, California; LP=Lincoln Park Zoo, Chicago, Illinois. /2/ Based on 7 da/wk feeding except for the order Carnivora in which the animals are fed 6 da and fasted the 7th. /3/ Lb/wk, unless otherwise indicated; figures in parentheses are no./wk. /4/ Vitamin formula: A, 5000 USP units; D_3, 1000 USP units; B_1, 1.0 mg; B_2, 1.0 mg; B_6, 0.5 mg; calcium pantothenate 3.0 mg; nicotinamide, 10.0 mg; ascorbic acid, 60.0 mg; B_{12}, 1.0 µg; folic acid, 0.25 mg. /5/ Dog biscuit formula: wheat flour, meat meal, bone meal, wheat bran, wheat germ meal, tomato pulp, irradiated dried yeast; dried corn fermentation solubles, calcite flour, manganese sulphate, potassium iodide, iron sulphate, copper carbonate, salt. Vitamin A feeding oil, dried skim milk, Brewer's yeast, turmeric, charcoal. Protein, 20%; fat, 1%; fiber, 2%. /6/ Milk mixture formula: salt, 2 t; sugar, 2 T; malted milk powder, 2 t; cereal, 1½ lb; evaporated milk, 16 oz; water, 26 oz. /7/ Dog food mix (lbs): meat, 100; kibbled dog biscuit, 25; powdered milk, 5; bone meal, 5; NaCl, 1; water, 5 gal. /8/ Equal parts honey and bran. /9/ In winter only. /10/ 30 lb in summer. /11/ 1.5 lb in summer. /12/ Grain mix formula (lbs): beet pulp, 300; rolled barley, 300; bran, 100; rolled oats, 75; ground corn, 100; linseed meal, 40; bone meal, 5; salt, 5; live yeast culture, 3. /13/ 9 lbs in winter. /14/ During corn season. /15/ Hay consumption is decreased 25% in summer months. /16/ GLF formula (lbs): 34% linseed meal, 200; wheat bran, 200; hominy feed and corn meal, 400; crushed oats, 419. 5; cane molasses, 200; beet pulp, 200; chopped alfalfa, 240; wheat germ meal, 60; Brewer's yeast, 40; irradiated yeast, 0.5; salt, 20; dicalcium phosphate, 15; ground limestone, 5. /17/ Fresh-cut alfalfa, approximately twice the amount of alfalfa pellets, is fed 3 da per week for 10 months of the year in place of alfalfa pellets. /18 Salt block available. /19/ Ebis almost twice as much for 10 da before and after annual moult; during moult, almost complete inappetence. /20/ Eats about 50% more daily for 2 autumn months. /21/ 23 lb in winter. /22/ Mellin's formula (given in a.m.): Mellin's food, 4 t; honey, 5 t; condensed milk, 1 t; vitamins, 4 drops; beef extract, 5 ml; warm water, 1 qt. /23/ Honey formula (given in p.m.): honey, 5 t; beef extract, 5 ml; vitamins, 4 drops; warm water, 1 qt.

Parts II and II list diets, as developed and used by the Philadelphia Zoological Garden, for captive wild animals. Although the diets are completely adequate for the majority of animals given below, certain rare species have not been tested.

Part II: BASIC DIETS

Values are g/100 g of ration, unless otherwise indicated.

	Ingredient	Diet A[1]	Diet B	Diet C	Diet D	Diet E	Diet F
1	Basic Mixture			31[2]	50[2]		
2	Ground yellow corn	15	15				
3	Ground whole wheat	15	10				
4	Ground whole barley	10					
5	Ground rolled oats	10	10				
6	Peanut meal	10					
7	Soybean meal	10	10				
8	Brewers' yeast	10	5				
9	Dried skimmed milk	10					
10	Alfalfa leaf meal	5	26				
11	Oystershell flour	2	2.5	2		2	
12	Iodized salt	1	1				
13	A-D feeding oil	2	0.5	2	3	2	
	Additional						
14	Linseed meal		10				
15	Brewers' grains		10				
16	Dry beet pulp[3]		45[4]				
17	Whole milk					2x/day	
18	Ground cooked meat	1:9 Basic Mix.[5]		55[6]	20		
19	Raw horse meat						20-100[7]
20	Ground raw meat					90	
21	Raw liver						10-50[8]
22	Chopped raw cabbage		5%				
23	Ground raw carrots		5%	10	20		
24	Hard-cooked eggs, shelled[9]				7		
25	Deterioration	2 wk[9]	2 wk[9]	48 hr[9]	48 hr[9]		

/1/ Press and refrigerate 24-28 hr before using. /2/ Basic mixture for Diet A. /3/ Mix with equal amounts water; let stand 1-2 hr before adding to other ingredients. /4/ Of total dry weight. /5/ Plus broth to make stiff mash. /6/ Ground. /7/ Or whale or beef, g/kg per body weight, daily. /8/ g/kg body weight, twice weekly. /9/ Refrigerated.

Part III: ANIMAL FEEDING

Diets are for adult animals, unless otherwise indicated.

	Animal	Diet[1]
	Omnivorous[2]	
	Mammalia	
1	Primates	A,S-1
2	Rodentia	A,S-1
3	Hyracoidea	A,S-1
4	Ursidae	1/2A,1/2 raw meat or fish; S-1
5	Suidae	A,S-1
6	Tayassuidae	A,S-1
	Aves	
7	Struthioniformes	1/2A,1/2B;S-1
8	Rheiformes	1/2A,1/2B;S-1
9	Psittaciformes[3]	A,S-1
10	Casuariiformes	A,S-1
11	Phasianoidea	A,S-1
12	Columbidae	A,S-1
13	Anatidae	A,S-1
14	Threskiornithidae	1/2A,1/2C;S-1
15	Phoenicopteridae	A,S-1
16	Gruidae	A,S-1
17	Rallidae	A,S-1

	Animal	Diet[1]
	Omnivorous[2] (concluded)	
	Aves (concluded)	
18	Eurypygidae	1/2A,1/2C;S-1
19	Carjamidae	1/2A,1/2C;S-1
20	Psophidae	A,S-1
	Herbivorous Mammalia[3]	
21	Artiodactyla[4]	B,S-2,S-3
22	Proboscidea	B,S-2,S-3
23	Perissodactyla	B,S-2,S-3
24	Hippopotamidae	B,S-2,S-3
25	Macropodidae	B,S-2,S-3
	Carnivorous[1]	
	Mammalia	
26	Viverridae	C
27	Canidae	C
28	Felidae,immature	E
29	Felidae[5], adult	F
30	Mustelidae	C,S-4
31	Procyonidae	C,S-4
32	Didelphidae	C
	Aves	
33	Falconiformes	C

	Animal	Diet[1]
	Carnivorous[2] (concluded)	
	Aves (concluded)	
34	Strigiformes	C
35	Ardeidae	C
36	Cochlearidae	C
37	Laridae	C
38	Corvidae	C
	Reptilia	
39	Iguanidae	C
40	Helodermа	C
41	Testudinidae	C
42	Eumeces	C
43	Ophisaurus	C
	Aves (Cage)[7,9]	
44	Passeriformes	D,S-5
45	Trogoniformes	D,S-5
46	Musophagidae	D,S-5
47	Momotidae	D,S-5
48	Coraciidae	D,S-5
49	Bucerotidae	D,S-5,S-6
50	Capitonidae	D,S-5
51	Rhamphastidae	D,S-5

/1/ Diets may be supplemented: S-1=citrus fruits, green vegetables, carrots (for bulk, increase these items); S-2=hay, q.s., green leaves, or fresh-cut grass (5-10 g/kg body weight); S-3=equal quantities apples, carrots, green lettuce, or cabbage (10-50 g/kg); S-4=apples and carrots; S-5=oranges, apples, grapes, cherries, and green lettuce; S-6=1-2 mice. /2/ Daily intake: 5-50 g/kg of body weight, depending on weight and activity. /3/ Small lories and parakeets need whole seed also. /4/ To start on diet, form a mash with water. /5/ Daily food intake: 1040 g/kg of body weight. /6/ Except swine. /7/ Daily food intake: 25-75 g/kg of body weight. /8/ Daily food intake: 20-100 g/kg of body weight with twice-weekly supplement of liver (see Part II, Diet F). /9/ Diet D may be combined with Diet C in varying proportions.

These are representative diets for a number of insects studied in nutritional research. Values for sterile diets are in brackets; insects maintained on sterile diets are from bacteria-free eggs. All values calculated (and rounded) as grams or milligrams per 100 grams or milliliters of diet.

		Orthoptera	Coleoptera	Lepidoptera				Diptera			
	Nutrient	Cockroach, German (Blatella germanica)[1] per 100g	Meal Worm, Yellow (Tenebrio molitor)[2, 3] per 100 g	Flour Moth (Ephestia sp)[2] per 100g	Corn Borer (Pyrausta nubilalis)[2] per 100g[4]	Rice Stem Borer (Chilo simplex)[2] per 100ml[4]	Bollworm, Pink (Pectinophora gossypiella)[2] per 100ml[4]	Fruit Fly (Drosophila melanogaster)[2] per 100ml[4]	Mosquito, Yellow Fever (Aedes aegypti)[2] per 100ml	Onion Maggot (Hylemya antiqua)[2] per 100ml[4]	Parasite of Spruce Budworm (Pseudoasarcophaga affinis)[2] per 100ml[4]
1	Calcium chloride, mg							[1.3]	[1.2]		
2	Iron sulfate (ferrous), mg							[1.3]	[1.2]		
3	Magnesium sulfate-$7H_2O$, mg							[25.0]	[20.0]		
4	Manganese sulfate-$7H_2O$, mg							[1.3]	[1.2]		
5	McCollum's salt mixture, g		2.0	2.0							
6	Potassium hydroxide, g						[+][5]				[0.172]
7	Potassium orthophosphate (mono-H), mg							[61]	[60]		
8	Potassium orthophosphate (di-H), mg							[61]	[60]		
9	Sodium chloride, mg							[1.3]	[1.2]		
10	U.S.P. salt mixture No.1, g	[3.0]									
11	U.S.P. salt mixture No.2, g									[0.2]	[0.066]
12	Wesson's salt mixture, g	4.0			[0.30]	[0.6]	[0.7]				
13	Casein[6], g	30[29]	17.0	17.0	[4.0]		[5.0]		[0.6]		
14	Cystine, mg						[100]		[20.0]		
15	Glutathione, mg								[1.0]		
16	Glycine, mg						[150]				
17	Amino acid mixture, g				[3.5][7]			[3.1][8]		[2.4][7]	[2.0][7]
18	Inosine, mg									[3.0]	
19	Ribonucleic acid, g	[0.5]						[0.1]	[0.1]	[0.1]	[0.1]
20	Thymine, mg									[0.4]	
21	Dextrin, g	[63]									
22	Glucose, g	31	69.0	68	[4.0]	[5.0]				[1.5]	[0.5]
23	Sucrose, g					[2.0]	[8.0]	[0.75]	[0.2]		
24	Cholesterol[9], g	1.0[0.5]	0.9	1.0	[0.15]	[0.06]	[0.3]	[0.04]	[0.003]	[0.01]	[0.1]
25	Ergosterol, g	[0.5]									
26	Linoleic acid, g				[0.15]						
27	Oil, corn, g	3.0					[1.0]				
28	Oil, soybean, g	[1.0]									
29	Oil, wheat germ, g			1.0							
30	Fatty acid mixture[10], g										[0.4]
31	Biotin, mg	0.06[0.025]	0.02	0.02		[0.05]	[0.002]	[0.02]	[0.005]	[0.002]	[0.0001]
32	Coba|amin (vitamin B_{12}), mg						[0.002]	[0.005]		[0.004]	
33	Choline chloride, mg	400[100]	30.0	50	[0.06]	[10.0]	[100]	[7.5]	[2.0]	[2.0]	[9.6]
34	Inositol, mg	200[97]		50		[5.0]			[4.0]		[9.6]
35	Niacin, mg	10.0[10.0]	1.6	5.0		[0.5]	[4.0]		[0.2]	[1.0]	[1.5]
36	Niacinamide, mg							[1.0]	[1.0]		
37	Pantothenic acid (Ca salt), mg	4.0[10.0]	0.8	5.0		[0.5]	[2.0]	[0.6]	[0.5]	[0.6]	[1.5]
38	Para-aminobenzoic acid, mg	[10.0]				[0.5]			[0.2]		[1.5]
39	Pyridoxine (HCl), mg	1.6 [10.0]	0.2	5.0		[0.25]	[0.5]	[0.3]	[0.4]	[3.0]	[1.5]
40	Pyridoxamine (HCl), mg								[0.002]		
41	Riboflavin, mg	1.8[10.0]	0.2-0.8	5.0		[0.25]	[1.0]	[0.24]	[0.2]	[0.24]	[1.5]
42	Thiamine (HCl), mg	1.2[10.0]	0.1	5.0		[0.5]	[0.5]	[0.15]	[0.2]	[0.15]	[0.5]
43	Brewer's yeast, g				[1.5]						
44	Carnitine, mg		0.15								
45	Co-enzyme A, mg									[0.15]	
46	Leaf factor, g				[1.2]						
47	Pteroylglutamic acid, mg	0.5[0.4]	0.0125-0.025	0.2		[0.05]	[0.5]	[0.6]	[0.06]	[0.6]	[0.5]
48	Thioctic acid, mg									[0.05]	
49	Agar-agar, g				[2.3]	[1.0]	[3.0]	[2.0]		[2.0]	[0.75]
50	Cellulose, g	30			[1.8]	[3.0]	[4.0]				
51	Sodium alginate, g						[0.5]				
52	Water, ml	[2.0]	9.0		[100]	[100]	[100]	[100]	[100]	[100]	[100]

/1/ Nymphs and adults. /2/ Larvae. /3/ Also for confused flour beetle (Tribolium confusum), except that carnitine is not required, and for Palorus ratsburgi. /4/ Agar base. /5/ 2 M solution to adjust pH to 6.5. /6/ Vitamin free. /7/ Mixture of 19 pure amino acids. /8/ Mixture of 18 pure amino acids. /9/ Cholesterol essential for all insects critically studied. /10/ Mixture of palmitic, stearic, oleic, linoleic and linolenic acids.

191. CULTURE MEDIA: PLANT TISSUES

	Component	Gautheret[1] mg/L	White[2] mg/L
1	$Ca(NO_3)_2 \cdot 4H_2O$	285	288
2	$CaSO_4$	0.2	65
3	$Fe_2(SO_4)_3 \cdot 6H_2O$	20	2.5
4	$MgSO_4 \cdot 7H_2O$	72	360
5	KCl	72	65
6	KNO_3	72	80
7	$KH_2PO_4 \cdot H_2O$	72	
8	$NaH_2PO_4 \cdot H_2O$		16.5
9	Na_2SO_4		200
10	H_3BO_3	0.02	1.5
11	$CoCl_2$	0.01	
12	$CuSO_4$	0.01	
13	$MnSO_4 \cdot 4H_2O$	0.4	4.5
14	$NiCl_2$	0.01	
15	KI		0.8
16	$Ti_2(SO_4)_3$	0.8	
17	$ZnSO_4 \cdot 7H_2O$	0.2	1.5
18	Glucose	20,000	
19	Sucrose		20,000
20	Niacin		1.0
21	Pyridoxine		0.1
22	Thiamine		0.1
23	Naphthaleneacetic acid	0.1	
24	Glycine		3
25	Agar	12,000	6000

/1/ For callus tissues. /2/ For callus and tumor tissues.

192. SYNTHETIC CULTURE MEDIA: PLANTS

All values are mg of component per liter of culture media. Those for amino acids are for DL-isomers.

	Component	Value
	Higher Plants	
1	H_3BO_3	2.86
2	$Ca(NO_3)_2 \cdot 4H_2O$	1680
3	$CuSO_4 \cdot 5H_2O$	0.08
4	$FeSO_4 \cdot 7H_2O$	5^1
5	$MgSO_4 \cdot 7H_2O$	493
6	$MnCl_2 \cdot 4H_2O$	1.8
7	$H_2MoO_4 \cdot H_2O$	0.02
8	KNO_3	505
9	KH_2PO_4	136
10	$ZnSO_4 \cdot 7H_2O$	0.22
	Algae: Chlorella[2]	
11	NH_4VO_3	0.02
12	H_3BO_3	2.86
13	$CaCl_2$	55^3
14	$Co(NO_3)_2 \cdot 6H_2O$	0.05^3
15	$CuSO_4 \cdot 5H_2O$	0.08
16	$FeSO_4 \cdot 7H_2O$	20
17	$MgSO_4 \cdot 7H_2O$	1740
18	$MnCl_2 \cdot 4H_2O$	1.8
19	KNO_3	2000
20	KH_2PO_4	1360
21	Na_2MoO_4	0.02
22	$ZnSO_4 \cdot 7H_2O$	0.02
23	Na citrate	200
	Algae: Blue-green	
24	NH_4VO_3	0.02^3
25	H_3BO_3	2.86
26	$CaCl_2$	55
27	$Co(NO_3)_2 \cdot 6H_2O$	0.05^3
28	$CuSO_4 \cdot 5H_2O$	0.08
29	$FeSO_4 \cdot 7H_2O$	20
30	$MgSO_4 \cdot 7H_2O$	740
31	$MnCl_2 \cdot 4H_2O$	1.8
32	KNO_3	2000^4
33	K_2HPO_4	2580
34	NaCl	40
35	Na_2CO_3	1500^5
36	Na_2MoO_4	0.2
37	Na_2CO_3	1500
38	$ZnSO_4 \cdot 7H_2O$	0.02
39	Na citrate	200
	Fungi: Aspergilli and Penicillia	
40	$FeSO_4 \cdot 7H_2O$	10
41	$MgSO_4 \cdot 7H_2O$	500
42	KCl	500
43	K_2HPO_4	1000
44	$NaNO_3$	3000
46	Sucrose	30,000
	Fungi: Basidiomycetes[6]	
47	$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$	0.02
48	H_3BO_3	0.57
49	$CuSO_4 \cdot 5H_2O$	0.04
50	$FeSO_4 \cdot 7H_2O$	0.15
51	$MgSO_4 \cdot 7H_2O$	500
52	$MnCl_2 \cdot 4H_2O$	0.04
53	KH_2PO_4	1500
54	$ZnSO_4 \cdot 7H_2O$	0.31
55	Glucose	10,000
56	Glutamic acid	1260
57	Thiamine·HCl	1
58	NH_4NO_3	1000
59	$(NH_4)_2C_4H_4O_6$	5000
60	H_3BO_3	0.06
61	$CaCl_2$	100
62	$CuSO_4 \cdot 5H_2O$	0.40
63	$FeSO_4 \cdot 7H_2O$	0.72
64	$MgSO_4 \cdot 7H_2O$	500
65	$MnCl_2 \cdot 4H_2O$	0.07
66	KH_2PO_4	1000
67	NaCl	100
68	Na_2MoO_4	0.04
69	$ZnSO_4 \cdot 7H_2O$	8.8
70	Sucrose	15,000
71	d-Biotin	0.005
	Bacteria: Photosynthetic	
72	NH_4Cl	1000
73	H_3BO_3	2.8
74	$CaCl_2$	100
75	$Co(NO_3)_2 \cdot 6H_2O$	0.05
76	$CuSO_4 \cdot 5H_2O$	0.02
77	$FeSO_4 \cdot 7H_2O$	20
78	$MgSO_4 \cdot 7H_2O$	250
79	$MnCl_2 \cdot 4H_2O$	0.05
80	K_2HPO_4	500
81	NaCl	3000^7
82	Na_2CO_3	2000^8
83	Na_2S	1000^9
84	Na_2CO_3	2000
85	$ZnSO_4 \cdot 7H_2O$	0.5
86	Glutamic acid	2000^9
87	d-Biotin	0.004^9
88	Thiamine·HCl	1.0^9
	Bacteria: Bacillus subtilis	
89	$(NH_4)_2HPO_4$	8000
90	$FeCl_3 \cdot 6H_2O$	33
91	$MgSO_4 \cdot 7H_2O$	614
92	$MnSO_4$	15
93	KCl	400
94	NaCl	300
95	Na_2SO_4	4000
96	$ZnCl_2$	10
97	Sucrose	100,000
98	Glutamic acid	2000
99	d-Biotin	0.02
100	Thiamine·HCl	4
101	Asparagine	2000
102	Choline·Cl	10
103	Folacin	0.02
104	l-Inositol	10
105	Uracil	2
106	DL-Ca pantothenate	4
107	Para-aminobenoic acid	2
108	Pyridoxine·HCl	2
109	Pyridoxamine·HCl	2
110	Riboflavin	4
111	Adenine sulfate	40
112	Guanine·HCl	40
113	Uracil	40
114	Xanthine	40
115	Citric acid	2000
116	$CaCl_2$	3
117	$FeSO_4 \cdot 7H_2O$	12.8
118	$MgSO_4 \cdot 7H_2O$	82
119	KH_2PO_4	3120
120	Glucose	1000
121	Glutamic acid	2000
122	d-Biotin	0.001
123	Thiamine·HCl	1
124	Alanine	1000
125	Arginine·HCl	400
126	Aspartic acid	1000
127	Cystine	200
128	Glycine	100
129	Histidine·HCl	200
130	Isoleucine	200
131	Leucine	200
132	Lysine·HCl	400
133	Methionine	200
134	Phenylalanine	200
135	Proline	200
136	Serine	200
137	Threonine	200
138	Tryptophan	200
139	Tyrosine	200
140	Valine	200
141	Choline·Cl	5
142	Folacin	0.01
143	l-Inositol	20
144	Niacin	0.5
145	DL-Ca-pantothenate	1
146	Para-aminobenoic acid	0.001
147	Pyridoxine·HCl	2
148	Riboflavin	0.1
149	Adenine sulfate	10
150	Guanine·HCl	10
151	Uracil	10
152	Coenzyme I	0.1
153	Putrescine	500
154	Na acetate	6000
	Bacteria: Lactobacillus leichmanni	
155	NH_4Cl	280
156	$FeSO_4 \cdot 7H_2O$	10
157	$MgSO_4 \cdot 7H_2O$	1400
158	$MnSO_4$	203
159	K_2HPO_4	2000
160	KH_2PO_4	2000
161	Na citrate	5000
162	Glucose	20,000
163	Glutamic acid	400
164	d-Biotin	0.005
165	Thiamine·HCl	1
166	Alanine	200
167	Arginine·HCl	200
168	Asparagine	200
169	Aspartic acid	200
170	Cystine	400
171	Glycine	300
172	Histidine·HCl	200
173	Isoleucine	300
174	Leucine	100
175	Lycine·HCl	600
176	Methionine	100
177	Phenylalanine	500
178	Proline	400
179	Serine	100
180	Threonine	100
181	Tryptophane	50
182	Tyrosine	400
183	Valine	200
184	Folacin	0.06
185	Niacin	1
186	DL-Ca-pantothenate	1
187	Para-aminobenzoic acid	0.04
188	Pyridoxine·HCl	2
189	Pyridoxamine·HCl	0.4
190	Riboflavin	1
191	Adenine sulfate	5
192	Guanine·HCl	5
193	Uracil	5
194	Xanthine	8
195	Na acetate	3600
196	Tween 80	
	Bacteria: Streptococcus faecalis	
197	NH_4Cl	1500
198	$FeSO_4 \cdot 7H_2O$	27
199	$MgSO_4 \cdot 7H_2O$	512
200	$MnSO_4$	30
201	K_2HPO_4	5000
202	NaCl	15
203	Na citrate	5000
204	Glucose	20,000
205	Glutamic acid	1000
206	d-Biotin	0.001
207	Thiamine·HCl	0.5
208	Alanine	500
209	Arginine·HCl	400
210	Asparagine	500
211	Aspartic acid	500
212	Cystine	200
213	Glycine	100
214	Histidine·HCl	200
215	Isoleucine	200
216	Leucine	200
217	Lysine·HCl	400
218	Methionine	200
219	Phenylalanine	200
220	Proline	400
221	Serine	500
222	Threonine	200
223	Tryptophane	200
224	Tyrosine	200
225	Valine	200
226	Folacin	0.02
227	Niacin	1
228	DL-Ca-pantothenate	0.5
229	Para-aminobenoic acid	0.2
230	Pyridoxine·HCl	0.5
231	Pyridoxamine·HCl	0.5
232	Riboflavin	0.5
233	Adenine sulfate	10
234	Uridine	0.2
235	Glutathione	20
236	Na acetate	5000
237	Tween 80	10

/1/ To be added twice weekly or as indicated by iron deficiency. /2/ And other simple green algae. /3/ Not yet shown to be generally required. /4/ May be omitted for nitrogen-fixing forms. /5/ For those strains which grow only at an alkaline pH. /6/ Wood-rotting types. Biotin and/or riboflavin may be required by some. /7/ For marine forms. /8/ For purple and green sulfur bacteria. /9/ For non-sulfur purple bacteria: additional compounds not listed (mg/L): Na succinate, 4000; glycerol, 2000; malic acid, 3000; K acetate, 1000; niacin, 1.0. /10/ Additional components not listed (mg/L): cysteine, 800; glutamine, 100; hydroxyproline, 50; norleucine, 200; cobalamin, 0.01; pyridoxal·HCl, 2; pyridoxal phosphate, 1; cytidylic acid, 10; sodium ethyl oxalacetate, 100.

193. DILUENTS FOR CULTURE MEDIA: ANIMAL TISSUES

In general, these diluents are used only in combination with naturally occurring body substances (e.g., blood serum, tissue extracts) and/or more complex chemically defined feeding solutions, as presented in the next table. pH of the final medium must be regulated. Values are mg/liter.

	Component	Tyrode I 1910	Earle	Hanks		Component	Tyrode I 1910	Earle	Hanks
1	NaCl	8000	6800	8000	6	$NaHCO_3$	1000	2200	340
2	KCl	200	400	400	7	Na_2HPO_4			60
3	$CaCl_2$	200	200	140	8	$NaH_2PO_4{\cdot}H_2O$	58[2]	125	
4	$MgCl_2{\cdot}6H_2O$	214[1]		100	9	KH_2PO_4			60
5	$MgSO_4{\cdot}7H_2O$		200	100	10	Glucose	1000	1000	1000

/1/ Calculated from 100 mg/L $MgCl_2$ in original formula. /2/ Calculated from 50 mg/L NaH_2PO_4 in original formula.

194. CHEMICALLY DEFINED CULTURE MEDIUM: ANIMAL TISSUES

Data adapted from Healy, G. M., et al., Proc. Soc. Exp. Biol. & Med. 85:71, 1955.

	Component	Value mg/L		Component	Value mg/L
1	L-Alanine	25	32	α-Tocopherol phosphate	0.01
2	L-Arginine	70	33	Cholesterol	0.2
3	L-Aspartic acid	30	34	Tween 80 (oleic acid)	5
4	L-Cysteine	240	35	Cocarboxylase (88% pure)	1
5	L-Cystine	20	36	Coenzyme A (75% pure)	2.5
6	L-Glutamic acid	75	37	Diphosphopyridine nucleotide (95% pure)	7
7	Glycine	50	38	Flavin adenine dinucleotide (60% pure)	1
8	L-Histidine	20	39	Glutathione	10
9	L-Hydroxyproline	10	40	Triphosphopyridine nucleotide (80% pure)	1
10	L-Isoleucine	20	41	Uridine triphosphate (90% pure)	1
11	L-Leucine	60	42	Adenine desoxyriboside	10
12	L-Lysine	70	43	Cystosine desoxyriboside	10
13	L-Methionine	15	44	Guanine desoxyriboside	10
14	L-Phenylalanine	25	45	5-Methyldesoxycytidine	0.1
15	L-Proline	40	46	Thymidine	10
16	L-Serine	25	47	Ribazol[1]	16
17	L-Threonine	30	48	α-Glucose	1000
18	L-Tryptophan	10	49	L-Glutamine	100
19	L-Tyrosine	40	50	Phenol red[2]	20
20	L-Valine	25	51	Sodium acetate	50
21	Vitamin A	0.1	52	Sodium glucuronate	4.2
22	Ascorbic acid	50	53	NaCl	6800
23	Biotin	0.01	54	KCl	400
24	Calciferol	0.1	55	$CaCl_2$	200
25	Choline	0.5	56	$MgSO_4{\cdot}7H_2O$	200
26	Folic acid	0.01	57	$NaH_2PO_4{\cdot}H_2O$	140
27	Inositol	0.05	58	$NaHCO_3$	2200
28	Menadione	0.01	59	$Fe(NO_3)_3$	0.1
29	Para-aminobenzoic acid	0.05	60	n-Butyl parahydroxybenzoate	0.2
30	Pyridoxal	0.025	61	Dihydrostreptomycin sulfate	100
31	Pyridoxine	0.025	62	Sodium penicillin G	1

/1/ As an initial solvent for fat-soluble constituents. /2/ pH indicator.

195. CULTURE MEDIA: SELECTED PROTOZOA

Part I: PARASITIC AMEBAE

In presence of bacterial flora derived from intestinal tract of host.

	Medium		Species Showing Growth[1]
	Diphasic		
	Solid Phase	Liquid Phase	
1	Slant of coagulated whole egg[2] with or without rice starch, rice flour or powder[3]	Ringer's or Locke's solution, or 0.85% NaCl with serum or liquid egg white overlay[4]	Dientamoeba fragilis, Entamoeba sulostomi, E. coli, E. gingivalis, E. histolytica, Endolimax nana
2	Same as 1 above	Same as 1 above, plus liver extract	Entamoeba coli, E. histolytica
3	Same as 1 above	No enrichment	D. fragilis, E. coli, E. histolytica, E. invadens, E. terrapini
4	Slant of coagulated serum	Same as 1 above	D. fragilis, E. coli, E. histolytica, Endolimax nana
5	Slant of liver infusion agar	Same as 1 above	Entamoeba coli, E. histolytica, E. invadens, E. terrapini
	Monophasic		
6	Same as liquid phase of 1 above, plus rice starch[5]		E. barreti, E. histolytica, E. invadens, E. ranarum, E. terrapini, E. thomsoni
7	Bacto-beef heart infusion, plus rice starch		E. histolytica, Iodamoeba buetschlii
8	Egg infusion with or without liver extract, blood clot extract, etc., with rice starch		D. fragilis, E. coli, E. histolytica, Endolimax nana
9	Alcoholic extract of egg yolk, and/or certain tissues, with rice starch		Entamoeba histolytica

/1/ Entamoeba sulostomi, E. coli, E. gingivalis, E. histolytica, Endolimax nana and Iodamoeba buetschlii cultivated at 37°C, transferred at 48 to 72 hr intervals; others cultivated at 25°C or lower and transferred less frequently. /2/ From 3 to 5 ml of egg emulsion, tubed, slanted, inspissated, and sterilized. /3/ Several mg per tube, sterilized by dry heat and added separately. /4/ Exact formulae unimportant; from 5 to 12.5% of enrichment is used. /5/ Dientamoeba fragilis also grows in this medium (Line 1) in the presence of C. perfringens. /6/ Probably a species of Clostridium. /7/ Entamoeba coli also grows in this medium (Line 1) in the presence of organism t.

Part II: ENTAMOEBA HISTOLYTICA

	Medium		Microbial Associate
	Diphasic		Monoxenic[1] Culture
	Solid Phase	Liquid Phase	
1	Slant of coagulated whole egg[2] with rice starch or flour[3]	Locke's solution with or without serum[4]	Actinomyces muris, Aerobacter aerogenes, Aplanobacter stewartii, Bacillus mesentericus, B. subtilis, Bacterium coronofaciens, Clostridium perfringens[5], Escherichia coli, Klebsiella pneumoniae, Neisseria catarrhalis, organism t[6,7], Proteus rettgeri, Salmonella paratyphi, S. schottmuelleri, S. typhosa, Serratia marcescens, Shigella ambigua, S. dysenteriae, S. paradysenteriae, S. sonnei, Staphylococcus albus, S. aureus, Streptococcus fecalis, S. hemolyticus, S. viridans, S. zymogenes
2	Slant of coagulated egg-white with rice flour[3]	Locke's solution with cholesterol, with or without B vitamins	Aerobacter aerogenes (α), Escherichia coli (α), organism t (α)[6]

/1/ Only one of the microbial associates or symbionts listed is required, in conjunction with the respective medium, to permit growth of the ameba. /2/ From 3 to 5 ml of egg emulsion, tubed, slanted, inspissated, and sterilized. /3/ Several mg per tube, sterilized by dry heat and added separately. /4/ Exact formulae unimportant; from 5 to 12.5% of enrichment is used. /5/ Dientamoeba fragilis also grows in this medium (Line 1) in the presence of C. perfringens. /6/ Probably a species of Clostridium. /7/ Entamoeba coli also grows in this medium (Line 1) in the presence of organism t.

Part II: ENTAMOEBA HISTOLYTICA (Concluded)

	Medium	Microbial Associate
	Monoxenic[1] Culture	
	Diphasic (concluded)	
3	Slant of liver infusion agar with rice starch or flour; 0.85% NaCl 9 parts, serum 1 part	Bacillus brevis, B. circulans, B. mesentericus, B. subtilis, Clostridium botulinum, C. pasteurianum, C. perfringens, C. tetani, Escherichia coli, Neisseria catarrhalis, Paracolobactrum coliforme, Staphylococcus albus, S. aureus, Vibrio comma
	Monophasic	
4	Egg yolk infusion with rice flour	Aerobacter aerogenes, A. cloacae, Kurthia zenkeri, Proteus vulgaris, Streptococcus equinus, S. fecalis, S. liquefaciens
5	0.85% NaCl 9 parts, serum 1 part, with rice starch, and methylene blue as indicator	Escherichia coli
6	Thioglycollate medium (BBL)[6] with serum, trypticase medium (BBL) with serum	Streptobacillus[9] (generic and specific identification not determined), Trypanosoma cruzi[10]
7	Proteose peptone, with liver extract, L-cystine, methionine, cholesterol, and rice flour, in balanced salt solution	Organism 1[6]
8	Twelve amino acids, B vitamins, nucleic acid, cholesterol, rice flour, in balanced salt solution	Organism 1[6]
9	Same as 8 above, with 20 amino acids	Organism 1[6]
	Axenic[11] Culture	
10	Whole egg medium with heat-killed bacteria and rice flour	Entamoeba histolytica[12] grows in this medium without microbial associate or symbiont
11	Mixed chick embryo cells, serum, in balanced salt solution	E. invadens and E. histolytica[13]
12	Proteose peptone with glucose	Mayorella pasteurensis
13	Proteose peptone without glucose	Acanthamoeba castellanii

/1/ Only one of the microbial associates or symbionts listed is required, in conjunction with the respective medium, to permit growth of the amebae. /6/ Probably a species of Clostridium. /8/ BBL: A Baltimore Biological Laboratories product. /9/ The streptobacillus is grown separately under a petroleum seal; amebae and dosage of penicillin are added. /10/ T. cruzi is grown separately and amebae added. /11/ No microbial associate or symbiont required, in conjunction with the respective medium, to permit growth of the amebae. /12/ Indefinite serial transfer not attained. /13/ E. histolytica requires anaerobiasis in H_2 or N_2 with 5% CO_2.

Part III: TRYPANOSOMATIDAE

Culture in absence of commensal organisms (axenic culture).

	Medium[1, 2]		Species[3] Showing Growth
	Diphasic		
	Solid Phase	Liquid Phase[4]	
1	15.6 g agar, 7 g NaCl, 330 ml defibrinated rabbit blood	Water of condensation	Leishmania tropica, Trypanosoma cruzi, T. duttoni, T. lewisi, T. melophagium, T. theileri, T. rotatorium, avian trypanosomes: various spp[3]
2	50 g bacto beef, 25 g bacto peptone, 7 g NaCl, 10 g bacto agar, 50 ml 1% glucose solution, 50 ml defibrinated guinea pig blood	Equal parts of peptone broth and dextrose solution	T. cruzi
3	50 g bacto beef, 20 g neopeptone, 5 g NaCl, 20 g bacto agar, 100 or 300 ml defibrinated rabbit blood	Locke's solution	L. brasiliensis, L. donovani, L. tropica, T. conorbini, T. cruzi, T. lewisi, T. pipistrelli, T. rangeli
4	3 g bacto beef, 5 g bacto peptone, 8 g NaCl, 15 g bacto agar, 330 ml citrated human or rabbit blood	Locke's solution	T. gambiense, T. rhodesiense
	Solid		
5	10-15 g agar, 10 g glucose, 100 ml horse meat broth, 1 L horse meat broth, 1 L defibrinated horse blood		L. brasiliensis, L. donovani, L. tropica, T. cruzi, T. melophagium, T. theileri, avian trypanosomes[5], T. rotatorium, Leptomonas ctenocephali, L. fasciculata
6	50 g bacto beef, 20 g neopeptone, 5 g NaCl, 20 g nobel agar, 100 ml defibrinated human or rabbit blood		Leishmania tropica, T. cruzi
7	31 g nutrient agar, 165 ml human citrated, inactivated plasma, 165 ml human red cells		T. gambiense, T. rhodesiense
	Semi-solid[5]		
8	1 part 3% agar, 8 parts Locke's solution with 0.2% glucose, 1 part rabbit serum		L. donovani, L. tropica, T. cruzi, Herpetomonas culicidarum
9	3 g agar, 150 ml defibrinated rabbit blood, 100 ml normal saline		L. donovani, L. tropica
	Liquid		
10	0.5 ml human or monkey blood, 0.5 ml 2% sodium citrate in 0.85% NaCl solution, 1 ml Ringer's solution (with 0.6% NaCl)		T. congolense, T. gambiense
11	2-2.5 ml Ringer's solution (with 0.6% NaCl), or 2-2.5 ml Tyrode solution, 2 ml citrated (1%) human blood		T. congolense, T. gambiense
12	Overlay of 3 above for T. cruzi, or overlay of 4 above for T. gambiense and T. rhodesiense		T. cruzi, T. gambiense, T. rhodesiense
13	10 g peptone, 10 g "casamino acids," 5 g NaCl, 2 g glucose, 100 mg each of alanine and glycine, 20 mg each of folic acid, nicotinamide, thiamin and choline		T. cruzi
	Synthetic		
14	Mixture of salts, metals, amino acids, vitamins, sorbitol, and hemin		H. culicidarum
	Dialysate		
15	Cellophane loop filled with Locke's solution suspended in tubes of 3		T. cruzi
	Chick Embryo and Tissue Culture		
16	Chorio-allantoic membrane		L. donovani, L. tropica, T. cruzi, T. gambiense
17	Blood or organs		T. cruzi, T. equiperdum, T. evansi, T. gambiense, T. rhodesiense
18	Tissue culture		L. donovani, T. cruzi

/1/ Ingredients of solid phase media, Lines 1 to 4, and of media given on Lines 5-13 are in amounts to be added to 1 L distilled water unless otherwise specified; test tube cultures usually contain 5 ml base (Lines 1-4), flask or plate cultures (Lines 1-7) contain varying amounts of base depending on size of container. /2/ Lines 1-15: cultures grown on media are usually maintained at temperatures of approximately 22-25°C; Lines 16 and 17: at 25-35°C; Line 18: at 37-39°C. /3/ Mammalian trypanosomatidae: Leishmania brasiliensis, L. donovani, L. tropica, Trypanosoma conorhini, T. cruzi, T. duttoni, T. lewisi, T. melophagium, T. pipistrelli, T. theileri, T. rangeli; T. congolense, T. equiperdum, T. evansi, T. gambiense, T. rhodesiense; avian trypanosomatidae; various species, not named because of uncertain taxonomic status; frog trypanosomatidae: T. rotatorium; insect trypanosomatidae: Herpetomonas culicidarum, Leptomonas ctenocephali, L. fasciculata. /4/ Lines 2 and 3: receive 2 to 3 ml overlay, flask cultures approximately 15 ml. /5/ Lines 8-14: varying amounts are used depending upon size of container.

The daily requirement of a nutrient may be altered -- either increased or decreased -- by a change in the daily intake of some other nutrient or by changes in other existing conditions of health or disease. The actual minimum requirement of many of the nutrients is as yet undetermined for man. Factors affecting the requirement are not available for "essential" fatty acids, vitamin E, inositol, pantothenic acid, para-aminobenzoic acid, chlorine, cobalt, copper, magnesium, manganese, and silicon.

Part I: FACTORS INFLUENCING BIOLOGICAL AVAILABILITY OF NUTRIENTS

	Increase	Decrease
		Energy: Total Calories
1		Decreased absorption, increased loss from the body, or defective utilization of protein, carbohydrate and fats. (See Items 2 to 14.)
		Protein
2	Adequate energy production from carbohydrate and fat.	Inadequate energy production from carbohydrate and fat: (a) low intake; (b) diabetes mellitus.
3	Proper amino acid balance in ingested protein.	Amino acid deficiency or imbalance in ingested protein.
4	Anabolic hormones; growth hormones.	Anti-anabolic hormones; adrenal cortical hormones.
5		Excessive heat or chemical treatment of protein.
6		Defective absorption caused by: (a) deficiency of digestive enzymes; (b) diarrhea; (c) intestinal parasites; (d) disease of the gastrointestinal tract.
7		Loss of protein in: (a) urine; (b) exudates; (c) transudates; (d) hemorrhage.
8		Loss of nitrogen from tissues in: (a) caloric deficiency; (b) burns; (c) trauma; (d) surgery.
		Carbohydrate
9		Decreased absorption caused by: (a) gastrointestinal diseases; (b) sprue; (c) hypoadrenalism; (d) hypothyroidism (e) panhypopituitrism.
10		Increased loss: glycosuria.
11	Increased gluconeogenesis.	Impaired gluconeogenesis.
12		Diabetes mellitus.
		Fat
13	Increased absorption caused by emulsifying agents.	Poor absorption caused by: (a) deficiency of fat-splitting enzymes; (b) deficiency of bile salts; (c) sprue, celiac disease and idiopathic steatorrhea.
14		Loss from body caused by: (a) chyluria; (b) chylous transudates.
		Vitamin A and Precursors
15	Increased absorption caused by: (a) ready release of food carotene; (b) emulsifying agents.	Decreased absorption caused by: (a) food carotene not readily released; (b) deficiency of bile salts; (c) defective absorption of fat in sprue, celiac disease, idiopathic steatorrhea, and deficiency of fat-splitting enzymes; (d) ingestion of mineral oil; (e) destruction of vitamin A in gastrointestinal tract by oxidizing agents (rancid fat, ferric iron); (f) low dietary fat.
16		Defective storage in liver disease (?).
17		Defective conversion of carotene to vitamin A: (a) diabetes; (b) hypothyroidism.
		Ascorbic Acid
18		Gastric achlorhydria.
19		Administration of alkali.
20		Destruction during preparation or storage of food: (a) high temperature; (b) alkali; (c) copper; (d) iron.
21		Increased loss in urine caused by certain drugs.
		Biotin
22		Raw egg white in diet.
23		Oral antibiotics.
		Choline
24	Oral antibiotics.	
		Cobalamin (Vitamin B_{12})
25		Poor absorption caused by lack of intrinsic factor in gastric juice (pernicious anemia).
		Vitamin D
26		Decreased absorption. (See Item 15 (b), (c), and (f).)
		Folic Acid Group (Folacin)
27		Decreased absorption caused by gastrointestinal disease.
		Vitamin K
28	Synthesis by intestinal microorganisms.	Oral antibiotics.

	Increase	Decrease
		Vitamin K (concluded)
29		Defective absorption. (See Item 15 (b), (c), (f).)
30		Inadequate intestinal flora in newborn infants.
31		Defective utilization in advanced liver disease.
		Niacin
32		Oral antibiotics.
33		Decreased absorption caused by desease of the gastrointestinal tract.
34		Decreased formation from tryptophan in vitamin B_6 deficiency.
		Pyridoxine Group (Vitamin B_6)
35		Loss in urine caused by isonicotinic acid hydrazide therapy.
		Riboflavin
36		Decreased absorption caused by disease of the gastrointestinal tract.
37		Increased excretion in association with protein breakdown.
		Thiamine
38		Decreased absorption caused by: (a) thiaminase in raw fish; (b) administration of live yeast and alkali; (c) low gastric acidity; (d) gastrointestinal diseases.
39		Loss caused by diuresis.
		Calcium
40	High dietary acidity.	Decreased absorption caused by: (a) low gastric acidity; (b) low dietary acidity; (c) phytic, oxalic, or benzoic acids in diet; (d) phosphorus in diet; (e) fatty acids in diet; (f) impaired fat absorption (caused by deficiency of bile salts, pancreatic disease, sprue syndrome, celiac disease, and idiopathic steatorrhea).
41		Increased loss of calcium caused by: (a) bed rest, immobilization; (b) anti-anabolic hormones; (c) primary and secondary hyperparathyroidism; (d) renal rickets.
42	Protein in diet.	
43	Lactose in diet.	Decreased ionised calcium caused by: (a) phosphorus retention; (b) alkalosis.
44	Citrates in diet.	
45	Vitamin D.	
46	Anabolic hormones.	
		Iron
47	Absorption increased by: (a) protein in diet; (b) ascorbic acid; (c) iron deficiency; (d) hemochromatosis.	Absorption decreased by: (a) low gastric acidity; (b) phytate in diet; (c) phosphate in diet.
48		Utilization decreased by infections.[1]
49		Increased urinary excretion in nephrosis.
		Phosphorus
50	Vitamin D.	Decreased absorption caused by: (a) phytate in diet; (b) excess calcium in diet; (c) administration of aluminum.
51		Increased excretion of phosphorus caused by: (a) alkalosis; (b) bone injury; (c) hyperparathyroidism; (d) immobilization.
		Potassium
52	Retention of potassium caused by: (a) anuria; (b) adrenal insufficiency.	Loss of potassium caused by: (a) metabolic alkalosis and acidosis; (b) administration of ACTH and adrenal cortical hormones; (c) negative nitrogen balance; (d) diarrhea; (e) recovery phase following acute renal failure.
		Sodium
53	Retention of sodium caused by: (a) administration of ACTH and adrenal cortical hormones; (b) hyperadrenalism; (c) hyperpituitrism.	Excessive loss in sweat caused by: (a) high environmental temperature; (b) fever.
54		Excessive loss in urine caused by: (a) adrenal insufficiency; (b) diuresis; (c) certain injuries and infections of the central nervous system.
55		Excessive loss from gastrointestinal tract in diarrhea and vomiting.

[1] Poor utilization cannot be corrected by iron administration.

The daily requirement of a nutrient may be altered -- either increased or decreased -- by a change in the daily intake of some other nutrient or by changes in other existing conditions of health or disease. The actual minimum requirement of many of the nutrients is as yet undetermined for man. Factors affecting the requirement are not available for "essential" fatty acids, vitamin E, inositol, pantothenic acid, para-aminobenzoic acid, chlorine, cobalt, copper, magnesium, manganese, and silicon.

Part II. FACTORS INFLUENCING NUTRIENT REQUIREMENTS PER SE

	Increase	Decrease
	Energy: Total Calories	
1	Growth.	
2	Pregnancy and lactation.	
3	Large body size.	Small body size.
4	Physical activity.	Physical inactivity.
5	Cold climate; exposure to cold.	Tropical climate.
6	Hypermetabolic states, such as: (a) fever; (b) hyperthyroidism; (c) leukemia; (d) acromegaly; (e) hyperadrenalism; (f) induced by certain drugs.	Hypometabolic states, such as: (a) hypothyroidism; (b) panhypopituitrism; (c) hypoadrenalism.
	Protein	
7	Growth.	
8	Pregnancy and lactation.	
9	Large body size.	Small body size.
10	Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
11	Protein deficiency syndromes: (a) Kwashiorkor; (b) starvation; (c) simple protein depletion, primary or secondary. (See Part I, Items 2 to 8.)	
	Carbohydrate	
12	Hyperinsulinism.	
	Vitamin A and Precursors	
13	Growth (e.g., bones, teeth).	
14	Vitamin A deficiency syndromes: (a) night blindness; (b) xerophthalmia; (c) follicular hyperkeratosis.	
	Ascorbic Acid	
15	Pregnancy and lactation.	
16	Growth.	
17	Metabolic stress,[1] (a) infectious disease; (b) hypermetabolic states; (c) trauma, burns, surgery; (d) toxic reactions from certain drugs.	
18	Tissue repair.	
19	High intake of tyrosine and phenylalanine in premature infants.	
20	Vitamin C deficiency: scurvy.	
	Choline	
21	Methyl group deficiency (fatty liver).	Methionine or methyl precursors in diet.
	Cobalamin (Vitamin B_{12})	
22	Cobalamin deficiency: (a) nutritional megaloblastic anemia; (b) pernicious anemia; (c) sprue (at times); (d) certain nutritional neuropathies.	
	Vitamin D	
23	Inadequate exposure to ultraviolet radiation.	Exposure to ultraviolet radiation.
24	Growth and dentition.	High dietary calcium and phosphorus.
25	Pregnancy and lactation.	
26	Vitamin D deficiency: (a) rickets; (b) osteomalacia.	
27	Hypoparathyroidism.	
	Folic Acid Group (Folacin)	
28	Pregnancy and lactation.	
29	Folic acid deficiency: (a) sprue; (b) nutritional megaloblastic anemia; (c) megaloblastic anemia of infancy; (d) megaloblastic anemia of pregnancy.	

	Increase	Decrease
	Vitamin K	
30	Pregnancy.	
31	Vitamin K deficiency: (a) hemorrhagic disease of newborn; (b) obstructive jaundice; (c) hypoprothrombinemia caused by oral antibiotics.	
	Niacin	
32	Large body size.	Small body size.
33	Increased caloric requirement.	Decreased caloric requirement.
34	Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
35	Niacin deficiency: pellagra.	High tryptophan intake.
	Pyridoxine Group (Vitamin B_6)	
36	Pregnancy.	
37	Pyridoxine deficiency (primary and secondary).	
	Riboflavin	
38	Growth.	
39	Pregnancy and lactation.	
40	Increased caloric requirement.	Decreased caloric requirement.
41	Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
42	Riboflavin deficiency.	
	Thiamine	
43	Increased caloric requirement.	Decreased caloric requirement.
44	Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
45	Increased proportion of calories derived from carbohydrate sources.	Increased proportion of calories derived from non-carbohydrate sources.
46	Thiamine deficiency: (a) beriberi: heart disease, neuropathy; (b) polyneuritis of chronic alcoholism and pernicious vomiting of pregnancy; (c) Wernicke's encephalopathy; (d) Korsakoff's psychosis; (e) delirium tremens.	
	Calcium	
47	Growth and dentition.	
48	Pregnancy and lactation.	
49	Rickets and osteomalacia.	
50	Calcium deficiency with or without tetany.	
	Fluorine	
51	Dental caries.[2]	
	Iodine	
52	Iodine deficiency: endemic goiter.	
	Iron	
53	Growth.	Menopause.
54	Pregnancy and lactation.	
55	Blood loss: (a) physiological (menstruation); (b) pathological.	
	Phosphorus	
56	Growth.	
57	Pregnancy and lactation.	
58	Phosphorus deficiency caused by rickets.	
	Potassium	
59	Potassium deficiency.	
	Sodium	
60	Sodium deficiency.	

[1] Available evidence suggests this but definite proof is lacking. [2] Fluorine has not been demonstrated to be an essential nutrient, but in amounts of 1 ppm is useful in prevention of dental caries.

The functions listed in the table requires the specific elements noted. In addition, carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur are required for the functions of synthesis of structural proteins, carbohydrates, fats and other organic compounds, and for formation of end products of metabolism.

1 BROMINE

Ingestion and Absorption: Traces in many foods. Probably completely absorbed from gastrointestinal tract. Distribution: Same as chloride in mammals. In Tyrian Purple (= brominated indigo) derived from viscera of marine gastropod (Purpura aperle); in dibromotyrosine in protein gorgonin, from coral (Primnoa lepedifera). Function: Not known.

2 CALCIUM

Ingestion and Absorption: Almost entirely as salts of inorganic or organic acids. Partial absorption from gastrointestinal tract. Absorption aided by vitamin D and low pH. Distribution: Insoluble calcium phosphate complex in bones, teeth in vertebrates. In exoskeleton of numerous invertebrates as calcium carbonate. Minute concentrations as soluble salts in body fluids, all species. As calcium carbonate in shell of certain eggs. Function: Component of supporting structure in higher forms, many lower forms. Vital electrolyte of cell and extracellular fluid. Protective shell of eggs.

3 CHLORINE

Ingestion and Absorption: Ingested principally as NaCl (see SODIUM, below). Distribution: Distribution similar to that of sodium but, in general, milliequivalent concentrations are lower. Chief anion of gastric juice. Also present in all other gastrointestinal secretions and extracellular fluids. Function: Although principal anion of extracellular fluid, function is unknown. Variation in Cl concentration appears to be better tolerated than in Na and most other electrolytes.

4 COBALT

Ingestion and Absorption: Trace constituent of many foods. Absorbed from gastrointestinal tract. Distribution: Trace distribution in many tissues, particularly glands and visceral organs, e.g., liver. Function: Component of vitamin B_{12} (cobalamin), required by some species from lowest to highest forms. Cobalt deficiency occurs in ruminants as "Pine" disease, salt sickness, bush sickness, "coast" disease. Cobalt enhances activity of certain peptidases.

5 COPPER

Ingestion and Absorption: Minute amounts in food as copper protein complexes. Poorly absorbed from intestine. Distribution: Higher concentrations in invertebrates than in vertebrates. Highest concentrations in hepatopancreas and gonads of Mollusca; lowest concentration in muscle. High concentration in gut of insects. Present in turacin (red pigment of feathers of turaco bird), injected Cu accumulates in liver, kidney. Liver is principal site of storage. Function: Erythropoiesis. Myelinisation of central nervous system. Maintenance of mammalian pigmentation. Trace quantities essential for hemoglobin and possibly iron-porphyrin-protein enzyme synthesis. Constituent of several enzymes present in animal tissues (polyphenol oxidase, tyrosinase, laccase, catechol oxidase, and ascorbic acid oxidase). Component of hemocyanin, respiratory pigment of numerous marine animals; component of hepatocuprein, hemocuprein-protein complexes found in liver, blood of certain mammals. Nutritional deficiency disease occurs in cattle, sheep, with inadequate intake or with increased intakes of molybdenum. Molybdenum and copper are mutually antagonistic in ruminant metabolism.

6 FLUORINE

Ingestion and Absorption: Traces in various foods, significant quantities in water in certain areas. Distribution: Present in bones, teeth. High concentration of 0.6-1.6% F in bones of sea animals. Function: Decreases incidence and severity of dental caries.

7 IODINE

Ingestion and Absorption: Trace amounts in various foods mostly as iodide or as component of organic compounds. Amount in food related to iodine content of soil. Absorbed from intestine and, in lower forms, through cell membranes. Distribution: Principally in thyroid of vertebrates. Component of thyroxine, diiodotyrosine and thyroglobulin. Trace amounts in other tissues. Relatively more iodide in marine fish and other marine animals. Function: Minute intake essential for growth and for prevention of goiter.

8 IRON

Ingestion and Absorption: Mainly as ferrous compounds from gastrointestinal tract. More absorption with iron deficiency states. Distribution: in blood hemoglobin, muscle hemoglobin, cytochrome of all cells. Stored in liver and spleen as ferritin (iron phosphoprotein). Function: Respiratory pigments of higher and lower forms. (Platyhelminthes contain hemoglobin.) Cytochrome is present in practically all cells.

9 MAGNESIUM

Ingestion and Absorption: Widely distributed in foods. Ingested as salt of inorganic or organic acid. Absorbed from intestine. Distribution: Minute amounts in plasma and extracellular water. Large amounts in intracellular fluid. Function: Essential electrolyte. Low concentrations increase cell irritability. Required for activity of several animal enzymes.

10 MANGANESE

Ingestion and Absorption: Traces present in most plant and animal foods. Poorly absorbed from gastrointestinal tract. Distribution: Particularly in liver, pancreas and hair. Also in all other tissues. Blood pigment of shellfish (Pinna squamosa) contains Mn rather than Fe or Cu. Function: Component of enzyme arginase. Enhances effect of certain proteinases. Necessary for growth of young animals (rabbits, rats). Also required for reproductive processes in many adult forms. Required for fertility of hen's eggs. Needed to prevent perosis in chicks.

11 PHOSPHORUS

Ingestion and Absorption: Occurs as phosphate in most foods. Absorbed from gastrointestinal tract in higher forms. Absorbed through cell membranes in lower forms. Distribution: Large quantities as phosphate complex of calcium in bone of vertebrates. Component of phospholipids (nerve and other tissues), phosphocreatine or phosphoarginine (muscle); as inorganic PO_4 in cell, extracellular fluid; as nucleoprotein in all tissues; and as adenosine triphosphate (ATP) in variety cells of higher and lower species. Intracellular inorganic phosphate phosphorus low compared to that of phosphate esters. Function: Important structural component of bone. Component of high energy P compounds (ATP, phosphocreatine, phosphoarginine, acetyl phosphate). Combines with intermediates in carbohydrate metabolism. Buffer in urine. Constituent of nucleoprotein. Component of phospholipids (intermediates in lipid metabolism).

12 POTASSIUM

Ingestion and Absorption: Ingested as inorganic salt in variety of foods. Absorbed from intestine. Absorbed through gills and cell membranes in many lower marine forms. Distribution: Principal cation of intracellular water. Small amount in extracellular water. Function: Essential cation of intracellular fluid.

13 SILICON

Ingestion and Absorption: Absorbed from intestine, inhaled particles deposit in lungs and give rise to serious effects. Absorbed through cell membrane of lower forms. Distribution: In skeletal structures and in supporting structures of certain Protozoa, Porifera and higher forms. Function: Protective and structural component of various lower animals forms.

14 SODIUM

Ingestion and Absorption: Widely distributed in foods as inorganic salt. More in foods of animal origin than in foods of plant origin. Taken as NaCl by many higher vertebrates including man. Absorbed from intestine in higher forms and through gills and cell membranes in lower forms. Distribution: Major part of body sodium is extracellular, much in bone. Some intracellular. Tissues vary in concentration of intracellular sodium, muscle containing only small amounts. Data on other than mammalian forms not available. Function: Chief cation of extracellular water. Essential for proper external environment of cells. Chief cation of intestinal secretions. Salts are important buffers of plasma, extracellular water and urine.

15 SULFUR

Ingestion and Absorption: As inorganic sulfates, organic sulfates and sulfhydryl sulfur of cystine and methionine. Distribution: Small amount of sulfate in extracellular H_2O. Relatively large amount in proteins and small amount in certain lipids. Function: Essential component of many proteins. Sulfuric acid secreted as digestive fluid in Ascidia. Sulfate is important anion in intracellular fluid. Sulfate used in detoxification reactions.

16 VANADIUM

Ingestion and Absorption: Extracted from marine muds by Ascidai. Distribution: In blood respiratory pigment of marine worm, Ascidia. Function: Component of respiratory pigment which provides oxygen transport in Ascidia.

17 ZINC

Ingestion and Absorption: Traces present in most foods. Absorbed from gastrointestinal tracts; in lower forms through cell membrane. Distribution: Largest quantities in pancreas, hair, nails, bone. Very large concentrations in certain oysters and herring. Function: Prosthetic group of carbonic anhydrase. indispensable for nutrition of growing rat. Also required by adult for reproduction. Needed for activation of certain proteinases.

	Element[1]	Occurrence and/or Function	Symptoms of Deficiency[2]	Symptoms of Excess[2]
1	B	Inverse relationship between boron level and water permeability of membranes and moisture content of tissues. (May be a constituent of cytoplasmic membranes). Necessary for cell division, and translocation of sucrose and possibly other sugars.	Terminal leaves necrotic, shed prematurely; internodes of terminal shoots shortened, usually rosetting; apical meristems blacken and die, general breakdown of meristematic tissue; roots short, stubby. Plants dwarfed, stunted. Flower development and seed production usually impaired or lacking.	Marginal necrosis in lower leaves, remainder of leaves dark green; death of most plants if present in considerable concentration.
2	Ca	Precipitates organic acids. Calcium pectate may be a constituent of the middle lamella.[3]	Leaves chlorotic, rolled, curled; breakdown of meristematic tissues in stems and roots, in acute cases death; roots poorly developed, lack fiber, may appear gelatinous. Symptoms appear near growing points of stems and roots. Little or no fruiting.	Chlorosis similar to iron or manganese deficiency.[4] Zinc and boron deficiency may be induced when soil reaction, e. g., pH, is high.
3	Cu	Associated with tyrosinase, a polyphenoloxidase involved in reduction of molecular oxygen. In ascorbic acid oxidase, which may be concerned in respiratory oxidation.[5] In laccase.[6]	Wilting of terminal shoots, often followed by death; leaf color often faded; carotene formation and pigmentation reduced.	Chlorosis similar to iron deficiency, followed by necrosis; permanent wilting of upper leaves; leaves may become wrinkled and necrotic at margins; fibrous roots stubby, poorly developed, brownish at tips; reduced growth; extreme cases death.
4	Fe	Associated with peroxidase, which breaks down peroxides and transfers active oxygen to oxidizable substances. In cytochrome oxidase, which plays a role in reduction of molecular oxygen.[5] In catalase, which effects the release of molecular oxygen from hydrogen peroxide.	Interveinal white chlorosis, appearing first on young leaves; tendency for chlorosis of all aerial parts, often becoming necrotic; in some cases leaves may be completely bleached, margins and tips scorched. Usually has an overall effect.	
5	Mg	In chlorophyll, which is essential for photosynthesis. Associated with co-carboxylase, which is the co-enzyme for the carboxylases; in enolase, which is necessary in glycolysis (from 2-phosphoglyceric acid to 2-phosphopyruvic acid); in hexokinase, which brings about transphosphorylation of glucose. Magnesium pectate may be a constituent of the middle lamella.[3]	Mottled chlorosis with veins green, leaf web tissue yellow or white, appearing first on old leaves; severely affected leaves may wilt and shed, or may abscise without the wilting stage; brittleness of leaves common, necrosis often occurs.	Usually on interveinal necrosis.
6	Mn	Associated with arginase (?), which converts arginine to urea. In an unidentified exozyme, which brings about catabolism of oxalacetic acid to pyruvic acid and carbon dioxide in respiration.	Mottled chlorosis with veins green and leaf web tissue yellow or white, appearing first on young leaves, may spread to old leaves; stems yellowish green, often hard and woody. Carotene development reduced.	Leaves pale, necrotic, bronzing at margins; similar to iron deficiency. With potato, small black spots on stem.
7	Mo	Associated with an unidentified enzyme (?), which is apparently required in ascorbic acid synthesis. Appears to effect the reduction of nitrate to ammonia.[7]	Light yellow chlorosis of leaves; leaf blade may fail to expand.	Lower leaves yellow with brown necrotic areas; in severe cases, upper leaves may be stunted, chlorotic and abscise.
8	N	In proteins, the chief organic constituents of protoplasm. In chlorophyll, which is essential for photosynthesis. Important in the assimilation of sugars. In many organic compounds.	In young plants stunted growth and yellowish green leaves; older leaves light green, followed by yellowing and drying or shedding, often abundant anthocyanins in veins; shoots short, thin, growth upright and spindly; flowering reduced; with apple and peach, fruit highly colored develop slowly, small when mature. Appears first on older leaves, but usually has an overall effect.	Leaves dark green, excessive vegetative growth; high transpiration; reduced yield of seed and fruit crops; may secure satisfactory yield of leafy vegetables of reduced quality.
9	P	In phospholipids, e.g., lecithin, which are constituents of cytoplasmic membranes. In nucleoprotein, a constituent of the nucleus and chromosomes. In adenosine di- and triphosphates, which are required for phosphorylation reactions, glycolysis and synthesis of sucrose, starch and proteins. Di- and triphosphopyridine nucleotide, coenzymes which accept and/or donate hydrogen in oxidation-reduction reactions.	Young plants stunted, leaves dark blue-green, sometimes purplish (with potato and certain other vegetables, leaves pale green); stems slender; often anthocyanins in veins, may become necrotic; with potato, meristematic growth ceases; fruits ripen slowly; planta often dwarfed at maturity.	
10	K	May be involved in action of fructokinase and other enzyme systems. Facilitates carbohydrate synthesis and translocation of carbohydrates.	Leaves of potato usually dark blue-green and leaves of monocotyledons pale green or streaked with yellow, with marginal chlorosis and necrosis, appearing first on old leaves; usually wrinkled, corrugated or crinkled between veins.	Leaves yellowish green; reduced growth; tendency toward calcium and magnesium deficiency.
11	S	In cystine and cysteine, which are present in all plant proteins. In glutathione, which may function as a hydrogen carrier in respiration. In mustard oil glycosides, which may tie up reserve food substances which would otherwise be toxic to cells.	Leaves light green to yellow, appearing first along veins of young leaves; stems often slender.	Necrosis or firing of older leaves of certain species or varieties.
12	Zn	Associated with an unidentified enzyme, which is directly necessary for synthesis of tryptophan, the precursor of indoleacetic acid.	Leaves chlorotic and necrotic, appearing first on young growth; rosetting; premature shedding; whitish chlorotic streaks between veins in older leaves and whitening of upper leaves in monocotyledons; chlorosis of lower leaves in dicotyledons.	Leaves yellow from zinc-induced iron chlorosis.

/1/ Carbon, hydrogen and oxygen have been intentionally omitted from table. These elements are constituents of carbohydrates, fats, proteins, vitamins, hormones, chlorophyll and other organic compounds occurring in plants. The bicarbonate ion is involved in ion absorption or exchange. Oxygen is the final receptor of hydrogen in aerobic respiration. Many of the metallic elements (as ions) that are indicated as being associated with enzymes serve as activators for the enzyme. /2/ Data applicable primarily to herbaceous crop plants. /3/ The middle lamella is an intercellular layer flanked on each side by the primary cell walls. /4/ Chlorosis due to the physiological unavailability of iron and manganese or reduced potassium. /5/ Terminal step in aerobic respiration. /6/ The enzyme is of limited distribution in plants and its function is a matter of speculation. /7/ Nature of relationship undetermined.

199. NUTRITIONAL CHARACTERISTICS OF CHEMICAL ELEMENTS: BACTERIA AND FUNGI

The specific elements listed are either required or exert an effect on the associated functions. Carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur are required for the synthesis of structural proteins, carbohydrates, fats, and other organic compounds, and for formation of end-products of metabolism.

	Species	Chemical Element	Occurrence and/or Function
		Heterotrophic Bacteria[1]	
1	Aerobacter aerogenes	Fe	Growth.
2		Mg, Mn	Associated with pyruvate → acetylmethylcarbinol.
3		Cr or Mn (partially replaceable by Al, Cu, Fe, Zn)	Fermentation.
4	A. indologenes	Fe	Associated with hydrogenase, formic dehydrogenase, formic hydrogenlyase[2], and cytochrome.
5	Azotobacter spp	Fe	Growth,
6		Ca (replaceable by Sr); Mo (partially replaceable by V)	Nitrogen fixation.
7		Co, Mg, Mn, Zn	Associated with oxalacetate decarboxylase.
8	Bacillus anthracis	Ca, Fe, K, Mg, Mn	Growth.
9	B. cereus	K	Spore formation.
10	B. subtilis	Fe, K, Mg, Mn, Zn	Growth and production of subtilin (antibiotic).
11	Brucella abortus	Mg or Mn	Normal growth of antigenic non-smooth variants.
12	B. suis	Fe, Mg, Mn	Growth,
13	Cellulomonas spp	Mg	Growth,
14	Clostridium acetobutylicum	Fe	Fermentation,
15		Mn, Zn	Associated with phosphatase.
16		Mo (partially replaceable by V)	Nitrogen fixation.
17	C. botulinum, C. histolyticus	Fe	Associated with polypeptidase.
18	C. butyricum	Mo (partially replaceable by V)	Nitrogen fixation.
19	C. perfringens	Mg	Cell division.
20		Fe	Fermentation.
21	Corynebacterium diphtheriae	Fe	Growth and formation of toxin and porphyrin.
22	Escherichia coli	Fe	Growth,
23		Mg, Mn	Associated with pyruvic dehydrogenase and enolase.
24	Hemophilus influenzae	Fe	In growth factor, hemin.
25	Klebsiella pneumoniae	Fe	Growth,
26	Lactobacillus arabinosus, L. casei	K, Mn	Growth.
27	L. lactis, L. leichmanii	Co	In growth factor, vitamin B_{12}.
28	Leuconostoc mesenteroides	K, Mn, P	Growth.
29	Propionibacterium jensenii	Mg, Zn	Associated with phosphatase.
30	Pseudomonas spp	B, Ca, Co, Cu, Fe, Mn, Mo, Zn	Growth
31	P. aeruginosa	Fe, S	Production of pyocyanine (antibiotic).
32		Mg, P, S	Production of fluorescent pigment.
33		Fe	Associated with cytochrome, cytochrome oxidase, catalase, & peroxidase.
34		Mg	Growth,
35	Serratia marcescens	Fe, Mg	Pigment formation.
36	Sporocytophaga myxococcoides	Fe, Mg	Growth and decomposition of cellulose.
37	Streptococcus fecalis	K, Mn, P	Growth.
38	Streptomyces fradiae	Fe, Zn	Production of neomycins.
39	S. griseus	Co	Production of vitamin B_{12}.
40		Fe, Cr, Zn, Co, Cu, Mn, Ni, Se	Production of streptomycins.
41		Fe, Zn	Production of grisein.
42	S. lavendulae	Fe, Zn	Production of streptothricin.
		Photosynthetic Bacteria[3]	
43	All species	Mg	In bacteriochlorophyll.
44	Non-sulfur purple bacteria	H_2	Molecular hydrogen oxidized as source of energy.
45	Sulfur purple bacteria	S, as sulfide, sulfite, or thiosulfate	Indispensable reducing agent in photosynthesis.
46	Sulfur green bacteria	S, as sulfide or thiosulfate	Indispensable reducing agent in photosynthesis.
		Chemoautotrophic Bacteria[3]	
47	Iron bacteria	Fe, Mn	Substrate, oxidized as source of energy.
48	Nitrifying bacteria	Cu	Nitrification (oxidation of ammonia and nitrite).
	Ammonia-oxidizing nitrifiers		
49	Nitrosomonas spp	N, as ammonia	Indispensable substrate, oxidized as source of energy.
	Nitrite-oxidizing nitrifiers		
50	Nitrobacter spp	N, as nitrite	Indispensable substrate, oxidized as source of energy.
	Sulfur-oxidizers, aerobic		
51	Thiobacillus spp	S, as sulfide or thiosulfate	Substrate, oxidized as source of energy.
	Sulfur-oxidizer, anaerobic		
52	Thiobacillus denitrificans	S, as sulfide or thiosulfate	Substrate, oxidized as source of energy.
53		N, as nitrate	Indispensable oxidizing agent.
	Sulfate-reducer		
54	Sporovibrio desulfuricans	S, as sulfate	Indispensable oxidizing agent.
55	Clostridium aceticum	H_2	Molecular hydrogen oxidized as source of energy.
56		CO_2	Employed as oxidizing agent.
57	Hydrogenomonas spp	H_2	Molecular hydrogen oxidized as source of energy.
58	Methanobacterium omelianski	H_2	Molecular hydrogen oxidized as source of energy.
59		CO_2	Employed as oxidizing agent.
		Fungi	
60	Aspergillus fumigatus	Fe, Zn	Production of gliotoxin and helvolic acid.
61	A. niger	Fe, Ni, Co, Al, Zn, Cr, Mn, Mo, Se, Pb, Cu, As, Te, U, Sb, W	Production of citric acid.
62		Fe	Production of gluconic acid.
63	Aspergillus sp	Fe, Zn	Production of citrinin.
64	Candida guillermondia, C. flareri	Fe	Production of riboflavin.
65	Penicillium citrinum	Fe, Mn	Production of citrinin.
66	P. notatum (chrysogenum group)	Zn, Fe, Mn, Cr, Cu, Al, Sn	Production of penicillin.
67		Fe, Zn	Production of gluconic acid.
68	P. patulum	Mn, Fe, Cu	Production of patulin and penicic acid.
69	Rhizopus delemar	Al	Production of amylase.
70	R. nigricans	Zn, Fe, Cu, Mn	Production of fumaric and lactic acids, and ethanol.

/1/ Utilize such organic materials as sugars, fatty acids, amino acids, and alcohols as sources of carbon and energy for growth. /2/ Not established as a separate and distinct enzyme. Considered by many investigators to be a mixture of formic acid dehydrogenase and other enzymes. /3/ Capable of growing with CO_2 as carbon source, by utilizing light energy. /4/ Also organic compounds, e.g., alcohols and acids. /5/ Capable of growing with CO_2 as carbon source and with energy derived from oxidation of inorganic materials. A few of these organisms grow only autotrophically, but most of them can develop either as heterotrophs or as autotrophs.

200. EFFECT OF CERTAIN SOIL FACTORS ON CHEMICAL ELEMENT DEFICIENCY AND EXCESS

The effects of soil pH and general soil characteristics on chemical element availability, uptake, or toxicity, is manifested by the appearance of deficiency or excess symptoms in the indicator organisms growing in the soil medium specified. Parenthetical expressions associated with pH values describe the pH-symptom relationship as follows: High = symptoms rarely occur outside the stated pH. Medium = symptoms occur most commonly within the stated pH. Low = symptoms occur at all pH values. For symptoms of deficiency and excess, see Table

Part I: FACTORS AFFECTING DEFICIENCY

Element		Soil pH	General Soil Characteristics	Indicator Organism
1	Al^{1}	5.5-8.0 (High)	Any soil of pH indicated.	Hydrangea.
2	B	<5.0;7.5-8.5 (Medium to low)	Calcareous soils with high Ca:B ratio; on leached acid sandy soils low in organic matter, particularly under intensive cropping.	Many, including, apple, beet, cauliflower, kale, turnip, celery, legumes, tobacco.
3	Co	(Low)	Soils of high pH^{2} and low Co content. Localized areas only.	Ruminants and other animals feeding on Co-deficient plants.
4	Cu	<5.0;7.6-8.5 (Medium to low)	Heath soils; peat; acid and calcareous sands and gravels.	Apple, pear, cereals, citrus, flax, legumes, lettuce, onion; peach, plum, etc.; tomato.
5	Mn	6.5-8.0 (High)	Calcareous soils, muck and peat.	Bean, beet, tree and bush fruits (except citrus), grasses, oats and other cereals, peas, potato, tomato.
6	Mo	4.5-6.5 (Medium)	Coarse-textured, leached acid soils, low molybdenum content.	Particularly legumes, sugar beet, brussels sprouts, cauliflower, kale, swede, citrus, lettuce, tomato.
7	Na	<5.5 (Medium)	Sandy, leached, inland soils.	Beet, carrot, celery, swede, turnip.
8	Zn	<5.0;7.6-8.5 (Medium to low)	Leached sands and gravels; muck and peat; calcareous soils.	Sugar beet, cacao, cereals, citrus and other tree fruits, clover, flax, various grasses, potato, swede, tomato, tung tree.
9	Ca	<5.0 (High) >9 (Medium)	Coarse-textured sandy soils; highly acid soils. Alkali soils with high exchangeable - Na - percentage (>40%).	Alfalfa, celery, clover, flax, peas, tomato. Alfalfa.
10	I	(Low)	Areas of calcareous rocks, river flats, alluvial soils. Inland areas.	Animals feeding on I-deficient plants.
11	Fe	>7.0 (Medium to high)	Particularly on calcareous soils; may be induced on acid soils by high concentration of heavy metals or P.	Apple, pear, sugar beet, citrus; peach, plum, etc.; grapes, pineapple, raspberry, strawberry.
12	Mg	<5.0 (Low) >9.0 (Medium)	Coarse-textured acid sandy soils; may be induced by heavy application or high content of K and Ca. Alkali soils with high exchangeable - Na - percentage (>40%).	Apple, sugar beet, cauliflower, cereals, citrus, corn, hops, kale, lettuce, oats, potato, tobacco, tomato, tung tree. Alfalfa.
13	N	<5.5 (Low)	Particularly coarse-textured acid soils and soils with low organic matter content.	Non-legumes. Legumes at low pH caused by molybdenum deficiency).
14	P	<6.5;7.5-8.2 (Medium to high)	Particularly acid soils; sands and certain calcareous and muck or peat soils.	Barley, beet, grasses, legumes, cotton, potato, swede, turnip.
15	K	<5.5; >7.5 (Medium to low)	Sandy soils, particularly when leached; coarse-textured calcareous soils.	Beet, corn, tree and bush fruits, legumes, potato, tobacco, tomato, tung tree.
16	S	<5.0 (Low)	Particularly on leached, eroded soils of areas remote from urban and industrial districts.	Cabbage, other brassicas, cotton, flax, legumes, tea.

/1/ Data refer to the role of aluminum in producing blue pigments in hydrangea flower. /2/ Availability of the element decreases with increasing soil pH. /3/ Sodium promotes vigor of certain higher plants, particularly celery, beet, and other root crops.

Part II: FACTORS AFFECTING EXCESS

Element		Soil pH	General Soil Characteristics	Indicator Organism
1	Al	<5.5 (High)[1]	Any soil of pH indicated.	Barley, French bean, sugar beet, carrot, celery, flax, leek.
2	B	>8.5 (High)	Coarse-textured soil irrigated with B-rich water.	Avocado, beans, blackberry, cereals, citrus; peach, plum, etc.; peas, potato, sunflower.
3	Co	<6.0	Acid soils with high concentration of heavy metals, particularly from industrial effluent.	Sugar beet, cauliflower, tomato.
4	Cu	<6.0	See cobalt.	Sugar beet, cauliflower, tomato.
5	Mn	<5.5 (High)	Often in rather impervious mineral soils.	Alfalfa, barley, French bean, kale, swede, lespedeza, potato, sweetclover, tomato, turnip, vetch.
6	Mo	>8.5 (High)	Soils derived from rocks high in molybdenum content, or receiving phosphate high in molybdenum.	Ruminants feeding on molybdenum-rich plants[2].
7	Na	>8.5 (High)	Alkali soils with exchangeable - Na - percentage (>15%). Saline soils or soils irrigated with water high in Na.	Almond, avocado, bean, cotton, oats, peas, wheat.
8	Zn	<5.0	See cobalt.	Sugar beet, cauliflower, tomato.
9	As	8.5 (Medium)	Soils with minerals containing As, or soils receiving continued As-sprays. Sandy soils low in Fe_2O_3.	Alfalfa, apricot, barley, oats, peach, tomato.
10	Cl	6.5-8.0 (Medium) >8.5 (High)	Saline soils containing chlorides, or soils irrigated with water high in chlorides.	Avocado, citrus, stone-fruits, grape.
11	F	<6.0 (High)	Soils in areas of industrial pollution.	Barley, buckwheat, collards, tomato.
12	Li	>8.2	Certain irrigated soils.	Citrus, corn, tomato, wheat.
13	Ni	<6[2]	Soils in areas of industrial pollution.	Beet, cabbage, clover, kale, oats, potato, tomato, turnip.
14	Se		Soils derived from Upper Cretaceous rocks and Upper Carboniferous limestone. Non-ferruginous soils in arid and semi-arid regions.	Animals feeding on Se-rich plants.

/1/ May occur with P deficiency. /2/ Inconsistent results with field plants.

201. EFFECT OF pH ON MACRONUTRIENT ABSORPTION: PLANTS

Plants were grown at pH 5-6 for 5 weeks in a dilute nutrient solution. At the end of this period they were placed for 3 days in a second solution containing (mEq per liter of solution): KNO_3, 5; $MgSO_4$, 2; KH_2PO_4, 0.06, and micronutrients. Following transfer to a third solution, containing 5 mEq KNO_3, 1 mEq $Ca(NO_3)_2$, 1 mEq $MgSO_4$, 0.06 mEq KH_2PO_4, and 0.5 mg B (as H_3BO_3) per liter of solution, uptake of ions during a 96 hour period was measured. Positive values indicated net absorption; negative values, loss from plant to the solution.

	Nutrient	Rate of Nutrient Uptake at pH[1]						
		3[2]	4	5	6	7	8	9
		mEq per plant per 96-hour period						
	Bermuda grass (Cynodon dactylon)							
1	K	3.38	4.61	4.53	4.33	5.17	4.53	
2	Ca	0	0.35	0.90	0.90	1.25	1.25	
3	Mg	0.82	1.07	1.07	1.15	1.48	1.23	
4	NO_3	10.69	10.14	10.45	10.08	10.14	10.08	
5	H_2PO_4	0.29	0.72	0.67	0.64	0.78	0.47	0.09
	Lettuce (Lactuca sativa)							
6	K	-0.44	3.14	5.07	6.66	6.09	5.86	6.53
7	Ca	-0.30	0.45	0.65	0.90	0.90	0.90	1.55
8	Mg	-0.33	0.66	0.99	1.15	0.99	0.82	1.15
9	NO_3	1.01	5.25	7.23	9.13	7.87	7.02	8.29
10	H_2PO_4	-0.11	0.26	0.45	0.65	0.58	0.42	0.16
	Tomato (Lycopersicon esculentum)							
11	K	-0.51	5.40	9.80	9.11	10.12	9.80	10.98
12	Ca	0	1.30	4.29	4.29	4.59	4.29	3.64
13	Mg	0	2.14	3.95	6.25	6.00	6.82	5.75
14	NO_3	4.69	26.48	25.12	25.84	24.94	20.61	20.29
15	H_2PO_4	0.03	1.51	1.85	1.89	2.86	1.52	0.14

/1/ pH adjusted by addition of either NaOH or H_2SO_4. /2/ Roots were visibly injured and plants failed to grow.

202. EFFECT OF pH ON ZINC ABSORPTION: EXCISED ROOTS

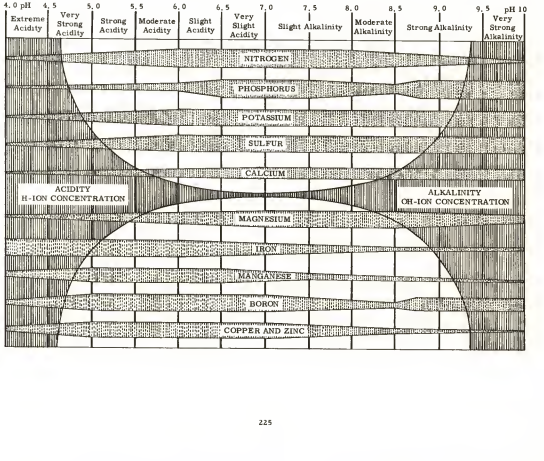
Data are applicable to excised, segmented roots of barley (Hordeum vulgare var. Sacramento), placed in solutions containing 0.0005 mEq zinc per liter. Values are mEq per 1000g roots, wet-weight, per 3 hr period.

	Acid-Base[1]	pH	Zn Uptake mEq/1000g roots		Acid-Base[1]	pH	Zn Uptake mEq/1000g roots
1		4.8	0.07	25		4.5	0.02
2		5.3	0.18	26		5.0	0.04
3	HCl-	6.4	0.33	27	HCl-	6.1	0.12
4	KOH	7.0	0.32	28	$Ca(OH)_2$	7.0	0.15
5		8.0	0.30				
6		9.0	0.26	29		9.0	0.18
7		4.6	0.05	30		4.6	0.02
8		5.2	0.09	31		4.8	0.03
9	HNO_3-	6.4	0.25	32	HNO_3-	6.1	0.08
10	KOH	7.0	0.29	33	$Ca(OH)_2$	7.0	0.12
11		8.0	0.31	34		8.0	0.14
12		9.0	0.24	35		9.0	0.19
13		4.4	0.04	36		4.3	0.01
14		4.9	0.08	37		4.8	0.03
15	H_2SO_4-	5.8	0.23	38	H_2SO_4-	5.4	0.05
16	KOH	7.0	0.30	39	$Ca(OH)_2$	7.0	0.12
17		8.0	0.32	40		8.0	0.15
18		9.0	0.25	41		9.0	0.17
19		4.4	0.03	42		4.0	0.01
20		5.2	0.10	43		4.3	0.01
21	H_3PO_4-	6.6	0.27	44	H_3PO_4-	6.2	0.11
22	KOH	7.0	0.31	45	$Ca(OH)_2$	7.0	0.16
23		8.0	0.31	46		8.0	0.17
24		9.0	0.14	47		9.0	0.14

/1/ Solutions made to pH 9 or above with base, then acidified with requisite amounts of acid. Initial concentration of KOH, 0.082 mEq per liter of H_2O; that for $Ca(OH)_2$, 0.090 mEq per liter.

203. EFFECT OF SOIL REACTION ON AVAILABILITY: CHEMICAL ELEMENTS

Diagram illustrates the general trend of relation of soil reaction (pH) and associated factors to the availability of plant nutrient elements. Each element is represented by a band as labeled. The width of the band at any particular pH value indicates the relative favorableness of this pH value and associated factors to the presence of the elements in question in readily available forms (the wider the band the more favorable the influence), but not to actual amount necessarily present. The latter is influenced by other factors, e.g., cropping and fertilization. The width of the heavily cross-hatched area between the curved lines at any pH is proportional to the hydrogen-ion concentration (intensity of acidity) to the left of pH 7, and to the OH-ion concentration (intensity of alkalinity) to the right of pH 7.



	Functions	Deficiency Signs	Excess Signs
1	VITAMIN A (Anti-xerophthalmia factor, axerophthol) Required by all vertebrates studied (man, cattle, dog, guinea pig, hedgehog, horse, monkey, rabbit, rat, chicken, turkey). May be formed within the organism from one of the carotenoid provitamins, alpha-, beta-, gamma-carotene, or cryptoxanthin. Exists as vitamin A_1 in marine fishes and land vertebrates, as both A_1 and A_2 in amphibia and anadromous and catadromous fishes, and as A_2 (in place of or in addition to A_1) in fresh-water fishes.		
	Stimulates growth and development. Maintains epithelium. Vitamin A is a precursor for retinene which, with the visual proteins, forms the photosensitive visual pigments (rhodopsin, porphyropsin, iodopsin).	Retarded growth of young (man, rat, chick, turkey); inability to stand on hind legs (swine). Localized overgrowth of bone (cattle, rat). Night blindness; photophobia (man). Degenerative changes in epithelium of eye; xerophthalmia, keratomalacia in severe deficiency (man, rat). Skin (man, rat) and mucosae (man), metaplasia, hyperkeratinization, cornification, desquamation. Optic nerve degeneration, possible result of skull overgrowth and pressure (cattle, rat). Decreased egg production (chicken); irregular estrus -- sterility, male (rat). Odontoblast atrophy (man, rat). Deficiency accentuated by: factors impairing digestion or absorption of fat, excessive ingestion of mineral oil, hyperthyroidism (inhibits conversion of provitamins to vitamin A_1).	Hypoprothrombinemia (rat); increased serum lipids, phosphatase; decreased serum proteins (man). Fragility, hyperostosis, cortical thickening of long bones, periosteal swellings, pain (man). Dry, exfoliated epithelium. Mouth desquamation, hyperemia of skin and mucosae (man). Liver enlargement (man). Telangiectasis.
2	ASCORBIC ACID (Vitamin C; anti-scorbutic factor) Required by man, other primates; guinea pig.		
	Protects hydrogen carriers. Promotes oxidation of fatty acids, oxidation of aromatic amino acids, conversion of folic acid to folinic acid, formation of intercellular substances. Increases phagocytic activity. Prevents and cures scurvy. Alleviates some effects of vitamin A lack and moderate excess. Prevents development of deficiency signs of vitamin E deficient diets (chick, guinea pig). Treatment of shock, wounds, infections. Protects adrenal oxy-steroids from destruction by liver (rat).	Loss of appetite, decline in physical activity; defective wound healing. Follicular keratosis (man); loss of luster, roughening of hair. Disorientation of cells in growing region of bone and teeth; beading of ribs; failure of chondroblast and osteoblast and ameloblast differentiation and maturation. Loosening of teeth; swollen gums. Anemia with decreased red cells; increase in circulating leukocytes. Failure of differentiation and maturation of fibroblasts. Capillary hemorrhages, particularly in subcutaneous and intramuscular areas. Swelling, atrophy, soreness of muscles leading to "face ache posture." Increased cholesterol in adrenals in early deficiency, decrease in late deficiency. Reduction of cytoplasm and indistinctness of cell membrane, increased respiration rate early in deficiency, decrease in late stages; lowering of temperature in late stages.	Hypervitaminosis doubtful if calcium content of diet is sufficient. Massive doses by injection lead to sudden death.
3	BIOTIN (Anti-egg-white factor; vitamin H) The need for the vitamin may be met under normal circumstances by intestinal bacterial synthesis in most animals. Need demonstrated for man, calf, dog, monkey, mouse, rabbit, rat, chicken, turkey.		
	Growth factor for all vertebrates studied. Believed to be required by all rapidly growing tissues. Involved in such metabolic processes, as: carboxylation and decarboxylation of Krebs Cycle acids; deamination of aspartic acid, serine, threonine; synthesis of citrulline, synthesis of unsaturated fatty acids. Prevention of "slipped tendon" (chick).	Seborrheic skin pathology. Scaly, greasy dermatitis (dog, monkey, rat, rabbit, chicken) followed by extreme hyperkeratosis after long deficiency. Scaly dermatitis in volunteers fed 200 grams of egg white daily (man). Spectacle alopecia (rodents); alopecia (monkey) may be extreme. Atrophy of lingual papillae (man). Spasticity (rat); paralysis of hindquarters (rat). Precordial distress; electrocardiographic changes (man). Anorexia, lassitude, sleeplessness, muscle pain (man); perosis (chick). Spontaneous deficiency rare, seen in chick. Feeding raw egg white (avidin) necessary to produce deficiency in most animals.	1 g/kg body weight not toxic to mice. Relatively non-toxic to all animals.
4	CHOLINE (No single analogue can carry out all functions of the vitamin; several compounds can replace choline in one or more of its functions). Required by most or all vertebrates, especially the young, including dog, guinea pig, rat, chicken, turkey.		
	Source of transferable (labile) methyl (CH_3) groups; is enzymatically transformed to betaine which transfers the methyl group. May be readily replaced as a methyl donor by betaine, dimethyl thetine, or methionine. Donor of methyl groups for synthesis of methionine (in presence of homocysteine), purines, etc. Synthesis of phospholipids, i.e., lecithin. Participates in creatine formation (rat). Precursor of acetylcholine. Essential for normal nutrition and egg production (chicken). Essential for lactation (hamster, rat). Necessary for normal liver function (dog, mouse, rat, chicken). A direct catalytic role of choline in intermediate metabolism has not been demonstrated. Therapeutic use: cure of fatty liver and certain forms of liver cirrhosis (dog, rat); prevention of perosis ("slipped tendon" (chicken, turkey)).	Increased mortality (chicken, turkey). Liver: fatty degeneration and cirrhosis of liver (dog, rabbit, rat); prolonged prothrombin and bromsulphalein times, changes being marked in animals on high protein diets (rat); liver carcinoma from chronic deficiency (mouse, rat, chick). Increased serum phosphatase (rat). Kidney is enlarged, hemorrhagic congestion, necrosis of renal tubule, epithelium and glomeruli (rat); granular atrophy; hypertension in consequence of early kidney lesions, decrease in alkaline phosphatase activity and fat deposition (rat). Paralysis (young rat). Muscle weakness (guinea pig). Decreased egg production, ovarian abortion (chicken, turkey). Intracranial bleeding in young, born of choline deficient females (rat). Small subcutaneous and adrenal hemorrhages; marked anemia (guinea pig).	Inhibition of erythrocyte formation (dog). Diarrhea (man). Edema of legs (man).

Functions	Deficiency Signs	Excess Signs
5 **COBALAMIN** (Vitamin B_{12}; vitamin B_{12a}; vitamin B_{12b}; cyanocobalamin; hydroxycobalamin)		
Required by most or all vertebrates studied. Probably the anti-pernicious anemia principle of liver.		
Growth factor (man, mouse, rat, swine, chicken, turkey). Utilization of oral cobalamin potentiated by gastric juice; in man, "intrinsic" factor necessary for the utilization of cobalamin, the "extrinsic" factor. In methylation reactions (rat, chick). Combined action with folic acid group. Therapeutic uses: pernicious anemia -- the vitamin is anti-anemic, relieves lingual manifestations and reverses degenerative changes in the spinal cord unless damage is irreversible (man); sprue (man).	Megalobiastic bone marrow (man). Macrocytic, hyperchromic anemia (man). Degenerative changes in the spinal cord. Glossitis (man).	Polycythemia of non-ruminant animals.
6 **VITAMIN D** (Anti-rachitic factor; calciferol; vitamin D_2; 7-dehydrocholesterol, vitamin D_3)		
Required by most vertebrates studied. Ultraviolet light converts the provitamins ergosteral and 7-dehydrocholesterol to D_2 and D_3 respectively.		
Normal development of bone. Enhances absorption and retention of Ca and P; promotes P reabsorption by the renal tubules. Maintains alkaline phosphatase at the bone site.	Retardation of growth (man, others). Rickets. Skeletal abnormalities and deformities varying with degree and duration of deficiency (man, rat, others). Skeletal abnormalities are scars of functional and structural change and may persist long after the deficiency has been relieved. Degree of restoration may be extensive and continue over long periods. Rapidly growing regions of bones are most affected; persistent over-proliferation of cartilage; enlargement of ends of long bones; softness, weakness of bones, and deformation of stress and posture; osteomalacia: decalcification, fragility of non-growing bone. Faulty calcification of teeth, similar to deficiencies of vitamins A and C. Hypocalcemia, hypophosphatemia. Increase in plasma phosphatase. Myasthenia; atony, skeletal and gut muscle. Tetany, convulsions, spasmodic closure of glottis (man, rat). Deficiency accentuated by factors impairing digestion or absorption of fat, excessive ingestion of mineral oil; pregnancy; lactation. Degree of toxicity is an individual characteristic.	Early symptoms: anorexia, thirst, lassitude. Later symptoms: nausea, vomiting, diarrhea, abdominal discomfort, weight loss and debility. Hypercalcemia, hyperphosphatemia. Deposition of Ca salts in various organs. Dense calcification in long bone metaphyses at the expense of diaphyseal calcification, in infants and growing young (man). Ca deposits, kidney damage and renal dysfunction; increased urinary excretion of Ca and P. Continued hypervitaminosis leads to death. Excessive doses may be cumulative. Hypercalcemia, high urinary Ca and renal damage have been noted eight months after treatment (125,000 - unit doses daily). The amount of dietary vitamin D which will produce signs of excess varies with individuals within the same species, and at different times within the same individual.
7 **VITAMIN E** (Alpha-, beta-, gamma-, delta-tocopherols; anti-sterility factor)		
Required by cattle, dog, guinea pig, hamster, mink, mouse, rabbit, rat, swine, chicken, duck, turkey. Significance, if any, in human nutrition, has not yet been established.		
Biological anti-oxidant; protects unsaturated fatty acids, vitamin A against peroxidation. Participates in oxidation-reduction reactions. Therapeutic uses: treatment of skin collagenoses (man); protects against such toxic agents as carbon tetrachloride, chloroform, alloxan.	Irreparable degeneration of the testicular germinal epithelium (bull, mouse, rat, chicken); uterine necrosis, seminal vesicle necrosis (rat). Reproductive failure (swine, rat). Reduced egg hatchability, death of the embryo (chicken). Acute muscle degeneration (dog, guinea pig, hamster, rabbit, rat, chicken, duck, turkey). Acute encephalomalacia, degeneration of the cerebellum, nerve cell degeneration (chick). Ataxia, tremors, weakness, opisthotonos (chicken). Paralysis (suckling rat, born of vitamin E deficient mother). Crestinuria. Generalized exudative diathesis (chick). Liver necrosis, degeneration (mouse, rat, swine). Some causes of deficiency signs, other than dietary deficiency of the vitamin are: any factor impairing digestion or absorption of fat, as inflammation of intestinal mucosa, sprue, or chronic diarrhea; excessive ingestion of mineral oil; relatively greater requirement during pregnancy and lactation.	None listed.
8 **FOLIC ACID GROUP** (Folacin; pteroylglutamic acid (PGA); folinic acid; citrovorum factor; vitamin M; vitamin B_c; vitamin B_{10}; factor U; L. casei factor; Norite eluate factor)		
Required by most vertebrates studied, except ruminants and others whose need is satisfied by intestinal bacterial synthesis. Essential for man, dog, guinea pig, fox, mink, chicken, duck, goose, turkey, fish, sulfa-treated lamb and rat.		
Growth and hematopoietic factor (monkey, fox, mink, chick, on purified rations). Production and utilization of formate. Methylation reactions. Introduction of the 2- and 8-carbon atoms into the purine ring and the amidine carbon into histidine. (Continued on next page)	Retardation of growth. Sprue (man, monkey), megaloblastic bone marrow (man, monkey, others), macrocytic, hyperchromic anemia (man, monkey); macrocytic anemia, with ultimate sniocytosis (chick, turkey); cytopenia (monkey, (Continued on next page)	Relatively non-toxic. Males more resistant than females (mouse). (Continued on next page)

	Functions	Deficiency Signs	Excess signs
8		FOLIC ACID GROUP (concluded)	
	Tyrosine oxidation. p-Aminobenzoic acid is a part of folic acid molecule. Vitamin-like action of PABA caused by above relations. Therapeutic uses: treatment of sprue (man); nutritional macrocytic anemia; certain megaloblastic, macrocytic anemias of infancy (man); macrocytic anemia of pregnancy (man); added to practical rations as a growth stimulant (mink).	chick); leukocyte abnormalities (monkey, rat, chick); infarction of the spleen (rat). Poor feather structure (chicken, turkey); abnormal feather pigmentation (chicken); graying of the pelage (rat). Perosis (chick, turkey). Impaired reproduction (rat, chicken); lowered hatchability of eggs (chicken). Impaired lactation (rat, mouse). Neck paralysis (goose, turkey). Diarrhea and the absorptive difficulties in sprue (disorders of calcium metabolism; impaired absorption of fat and of vitamins).	Death by obstruction of the renal tubules with precipitated folic acid follows intake of toxic amounts. Intravenous LD_{50} = 600 mg/kg body weight (mouse); 500 mg/kg (rat); 410 mg/kg (rabbit); 120 mg/kg guinea pig.
9		INOSITOL (Myo-) (Mouse anti-alopecia factor; Bios I) Required by mouse and possible cotton rat and hamster.	
	Has been reported to stimulate growth when added to rations deficient in thiamine (rat) and to rations containing sulfonamides (rat, swine). Lipotropic factor. Prevents encephalomalacia and exudative diathesis in vitamin E deficiency (chick). Suggested essential for reproduction (hamster). Of doubtful significance as a vitamin.	Characteristic alopecia (loss of hair) followed by severe dermatitis -- mouse (under certain dietary conditions).	Non-toxic, so far as known.
10		VITAMIN K (Anti-hemorrhagic factor; phylloquinone) Required by man, dog, mouse, rabbit, rat, canary, chicken, duck, goose, pigeon, turkey, and others. In mammals, bacterial synthesis may satisfy the need in whole or in part.	
	Essential for the production of prothrombin in liver. A number of synthetic products having a quinoid nucleus have vitamin K activity, e.g., menadione (2-methyl-1,4-naphthoquinone).	Decline or failure of prothrombin synthesis. Decrease in blood prothrombin content, resulting in increased bleeding tendency after even slight trauma, multiple hemorrhages throughout all tissues (man, chicken); increased clotting time (man, others).	Toxicity relatively low. Vomiting (man); vomiting after oral dose of 180 mg of menadione (synthetic vitamin) (dog). Porphyrinuria (man, dog), albuminuria (dog). Prolonged clotting time (rabbit); cytopenia, hemoglobinemia (mouse). Lethal dose is 350 to 500 mg/kg body weight (rats).
11		NIACIN (-AMIDE) (Nicotinic acid (-amide); pellagra preventive (P.P.) factor; anti-blacktongue factor). Required by all vertebrates studied except calf, horse, sheep, whose need is supplied by intestinal flora. Most animals synthesize niacin from tryptophan. Animal tissues contain niacinamide; plant tissues contain mainly niacin.	
	A component of di- and triphosphopyridine nucleotides (DPN, Coenzyme I; TPN, Coenzyme II) which function as hydrogen acceptors in more than 50 metabolic reactions. Stimulates gastric secretion.	Delayed growth and development of young; diarrhea, dermatitis, and dementia, the "triad" of pellagra. Bilateral, symmetrical dermatitis, aggravated by sunlight, heat, inflammation (man, only), rarefaction of corium, keratinization, atrophy of sebaceous glands, desquamation. Swollen gills (trout). Poor feathering (chick). Stomatitis (man, dog, fox, swine, chicken, turkey); smooth glossitis (man); black-tongue (dog, cat, chick); large intestine -- atrophy, ulceration, cyst formation (man, dog, swine), diarrhea (man, dog, calf, rabbit, chick, duck, turkey); achlorhydria (man, swine); salivary drooling (dog). Macrocytic anemia (man, dog, rabbit, swine); leukopenia (dog, rabbit). Retrobulbar neuritis (man); encephalopathy, headache, dizziness, depression, delusions, dementia; locomotor difficulties, tremors, jerky movements; rigidity; altered tendon reflexes, numbness, paralysis (man). Perosis ("slipped tendon" -- chick, turkey poult). The syndrome of deficiency symptoms is referred to as "pellagra" in man and "blacktongue" in dogs, cats, and other animals.	Death follows very large doses; dogs on 2 grams/day die within 20 days; 2% niacinamide in diet inhibits growth (chick); 1% causes fatty livers; large doses of niacin cause ketosis (rat). Burning and itching of skin; elevation of skin temperature (man). Peripheral vasodilation (man). Paralysis of the respiratory center (rat). Ratio therapeutic dose: toxic dose = 1:1000.
12		PANTOTHENIC ACID Required by most or all vertebrates studied, including calf, dog, fox, guinea pig, hamster, monkey, mouse, swine, rat, chicken, duck, pigeon, turkey, and possibly man.	
	Growth factor for the animals mentioned above. As a component of Coenzyme A, functions in: enzymatic acetylation; fat, protein and carbohydrate metabolism; fat, phospholipid, and steroid synthesis.	Retarded growth in all animals. Specific dermatitis of mouth and feet (chicken); eczematous dermatitis (rat). Achromotrichia (monkey, dog, fox, rat, mouse), spectacle alopecia (rat). Myelin degeneration of peripheral nerves (chick); chromatolysis of dorsal root ganglion cells (chick, swine). Spastic abnormalities of hindquarters, abnormal gait, ataxia (dog, mouse, swine); convulsions (dog). Hemorrhagic necrosis of adrenals. Secretion of red pigment by the Harderian gland ("bloody pigment" -- rat). Diarrhea with bloody stools (dog); anorexia, diarrhea, colitis (monkey, swine); necrosis of intestinal epithelium, abscesses followed by ulceration (rat). Anemia (dog, rat, monkey, swine). Necrosis of kidney (rat). Increased deposition of liver fat (dog, chick). Failure and abnormalities in reproduction, ocular changes. Burning sensations of hands, feet (man); increased non-protein nitrogen in severe deficiency (dog), death in severe deficiency.	100 grams have been given to man without ill effects. LD_{50} mouse: orally, 10 g; subcutaneously, 2.7 g; intraperitoneally, 0.9 g. LD_{50} rat: subcutaneously, 3.4 g/kg body weight.

	Functions	Deficiency Signs	Excess Signs
13	PYRIDOXINE (VITAMIN B_6) GROUP (Pyridoxal, pyridoxamine, anti-acrodynia factor; factor Y) Required by most or all vertebrates studied, including man, synthesized by intestinal organisms in rat. Requirement by animals is increased with increased dietary protein, linseed oil meal, sucrose, and apparently decreased with increased dietary essential fatty acids, aureomycin. Occurs largely as pyridoxal in animal products and as pyridoxamine in plant products. In animals the three forms (pyridoxine, -al, -amine) are equally active when given by injection, but pyridoxine is the most active when administered orally.		
	As coenzyme (pyridoxal phosphate) for transaminase and codecarboxylase systems, kynurinase, cystathionase, serine and threonine dehydrase, cysteine desulfhydrase, and racemizing enzymes; in deamination of amino acids and the formation of urea nitrogen; in conversion of tryptophan to niacin; in metabolism of fatty acids. Necessary for normal adrenal-cortical function. Therapeutic uses: treatment of muscular dystrophies associated with pellagra (man); hyperemesis gravidarum (nausea of pregnancy); seborrheic dermatitis sicca (man).	Retarded growth (man; infant; guinea pig, rabbit, monkey, rat, chick); appetite and weight loss, reduced egg production, death (chick). Hypochromic anemia (man: infant); polymorphonuclear leukocytosis, lymphopenia (man); hypocromic, microcytic anemia with anisocytosis and irregular reticulocytosis (dog, swine, monkey, duck, chick); poikilocytosis (cattle), dilation, hypertrophy of right auricle and ventricle; increased plasma urea and NPN tachycardia and cardiac embarrassment (rat); mucus accumulation in thorax (dog); impaired antibody production (rat); degeneration in myelin sheaths of peripheral nerves and spinal cord (dog, swine); convulsions, epileptiform fits (rat, swine, chicken); ataxia (swine); convulsions (man; infant); weakness, nervousness, irritability, insomnia (man); deficiency signs produced by ingestion of desoxypyridoxine; seborrhea-like lesions about eyes, nose, mouth; cheilosis, glossitis, stomatitis (man); denudation of hair from paws, snout, earlips, thickening of ears (rat); dermatitis, bald patches (monkey). Increased urea, ammonia, uric acid, creatinine (dog); tryptophan metabolites in urine (dog, hamster, mouse, rat); large amounts of xanthurenic acid (man). Anorexia, unthriftiness (cattle).	Convulsions 24 hr after LD_{50} dose (rat). Daily feeding of 10 mg/kg body weight for 3 months had no effect (monkey, dog, rat). LD_{50} rat: subcutaneously, 3 g/kg; body weight; orally, 4 g/kg.
14	RIBOFLAVIN (Vitamin B_2, or G; lactoflavin, ovoflavin, hepatoflavin) Required by most or all vertebrates studied.		
	As riboflavin-5-phosphate in flavo-protein enzymes, e.g., "Warburg's yellow enzyme," cytochrome-c-reductase, riboflavin-adenine-nucleotide. As prosthetic group in enzymic hydrogen carriers, e.g., D-amino acid oxidase, xanthine oxidase, succinic dehydrogenase. Role in the visual mechanism of the retina.	Cessation or retardation of growth (rat, others). Epidermal atrophy, dermatitis, greasy scaling especially of nasolabial folds, cheeks, chin (man); cheilosis, angular stomatitis, lesions of lip and mouth corners (man). Myelin degeneration of nerves (dog, mouse, rat, swine, chicken); central neuritis (man); lack of coordination, faulty grasp reflex (monkey); curled toe paralysis (chicken); partial paralysis of legs (rat). Muscle weakness (dog, monkey). Mild photophobia, dimness of vision and decline of visual acuity; soreness of eyes and lids (man); cornea -- cloudiness, vascularization, cataract, opacity, ulceration (man, dog, rat). Congenital skeletal malformations in offspring of riboflavin-deficient females (rat). Requirement increased in pregnancy and lactation.	5,000 times the therapeutic dose is tolerated (rat, mouse). Toxic amounts intraperitoneally cause anuria, renal concretions (rat). Paresthesia, itching (man).
15	THIAMINE (Vitamin B_1; aneurin) Required by most or all vertebrates studied, except ruminants whose need is satisfied by intestinal synthesis.		
	Essential for normal growth, appetite, digestion, gastrointestinal tonus, nerve activity, carbohydrate metabolism (as cocarboxylase participates in decarboxylations, oxidations, dismutations, and condensations leading to CO_2 formation).	Retardation of growth; anorexia (man, others). No peripheral nerve degeneration (mammals). Convulsions, hyperesthesia, anesthesia, opisthotonos (pigeon, chicken, turkey). Dilation of the heart, myocardial lesions (dog, fox, rat, swine); bradycardia (monkey, cat, dog, rat, swine). Edema (dog, fox, rat, swine). Gastrointestinal disturbances (man). Accumulation of pyruvic acid in blood and tissues. Decrease in urinary citric acid (rat). Deficiency disease in man: beriberi (sometimes subdivided into cardiac, wet, and dry [neuritic, paraplegic] beriberi).	Vascular: hypotension (man, dog, rabbit).
16	ESSENTIAL UNSATURATED FATTY ACIDS (Arachidonic acid, linoleic acid, linolenic acid) Required by rat, mouse, guinea pig, swine, others. Ordinarily not regarded as a vitamin.		
	Essential to growth and reproduction (rat). Serve as building units of the phospholipids. Catalyze the oxidation of saturated fatty acids in vitro. Exercise a protective action in pyridoxine deficiency (rat).	Eczema (man). Retardation or cessation of growth; metabolic rate; scaliness on feet and tail; alopecia; disturbances in reproduction; kidney and urinary tract lesions; increased water intake (rat).	Changes from normal in composition of stored fat.

205. NUTRIENTS: CALORIE VALUE

Values are Calories per gram of ingested nutrient.

P = plant; A = animal; F = fiber; M = mixed; NFE = nitrogen-free extract.

	Nutrients for:		Total[1]	Lost, Rumen Gas[2]	Lost, Feces	Virtually Absorbed[3]	Lost Urine	Metabolized Energy Net[4]	Av.[5]
	Man								
1	Protein	P	5.65		0.85	4.80	1.06	3.74	4.0
2		A	5.65		0.15	5.50	1.21	4.29	
3	Carbohydrate	P	4.15		0.15	4.00	0	4.00	4.0
4		A	3.90		0.10	3.80	0	3.80	
5	Fat	P	9.30		0.95	8.35	0	8.35	9.0
6		A	9.40		0.45	8.95	0	8.95	
	Monkey								
7	Protein	P	5.65		0.56	5.09	1.68	3.41	3.0
8		A	5.65		0.56	5.09	2.04	3.05	
9	Carbohydrate	P	4.1		0	?	0	?	
10	Fat	P	9.3		0	?	0	?	
	Cattle								
11	Protein	P	5.65		1.64	4.01	1.30	2.71	2.7
12	Carbohydrate	F	4.25	0.33	1.89	2.03	0	2.03	2.6
13		NFE	4.23	0.47	0.95	2.81	0	2.81	
14	Fat	P	8.72[6]		2.90	5.82	0	5.82	5.8
	Chicken								
15	Protein	M	5.70		1.37	4.33	0.87	3.46	3.5
16	Carbohydrate	M	4.20		0.84	3.36	0	3.36	3.4
17	Fat	M	9.47[7]		1.89	7.58	0	7.58	7.6

/1/ By bomb calorimeter. /2/ From fermentation of fiber and NFE. A 550 kg cow may lose 4000 Calories/da (400 liters methane). /3/ Total calorie value minus that lost in feces (in rumen gas and feces for ruminants). /4/ Net physiological energy available for heat, activity, growth. /5/ Average values rounded off. /6/ Mean of 7.96 for fat from roughage and 9.47 for fat from grain. /7/ From grain.

206. FEED UTILIZATION, ACCUMULATIVE EFFICIENCY FOR GROWTH: VERTEBRATES

Unless otherwise indicated, values are grams gain in body weight per gram of feed[1] consumed (or pounds gain per pound of feed consumed). Values are calculated by dividing gain in weight from birth to per cent of mature weight by total weight of feed consumed since birth.

MW = mature weight

	Species		10% MW	25% MW	50% MW	90% MW
1	Cattle, dairy, large	♂	0.45	0.26	0.17	
2		♀	0.54	0.31	0.16	0.05
3	Cattle, dairy, small	♂	0.39	0.33	0.16	
4		♀	0.44	0.27	0.20	0.07
5	Cattle, beef	♂	0.62	0.30	0.15	
6		♀	0.61	0.25	0.14	
7	Rat, Sprague-Dawley	♂	0.41	0.31	0.15	
8		♀				
9	Rat, Wistar	♂	0.44	0.34	0.14	
10		♀				
11	Swine[2]	♂				
12		♀	0.37[3]	0.27[3]	0.20[3]	
13	Chicken, white leghorn	♂	0.45	0.41	0.33	
14		♀	0.45	0.4	0.3	0.14
15	Chicken, heavy breeds	♂	0.53	0.45	0.35	
16		♀	0.54	0.43	0.33	
17	Turkey, Beltaville small[4]	♂	0.55	0.42	0.34	0.19
18		♀	0.50	0.37	0.31	

/1/ On a dry weight basis. /2/ Based on 56-day weaning weight, and feed consumption figures calculated for periods: 56-98 days, 98-140 days, and 140-180 days. /3/ Extrapolated. Calculated on basis of mature weight of 600 pounds. /4/ Values for broad-breasted bronze turkeys are the same, but a value of 0.23 is given at 90% mature weight.

207. NUTRIENTS, APPARENT DIGESTIBILITY AND ABSORBABILITY: VERTEBRATES

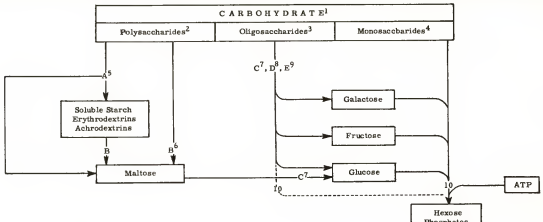
Values are grams of protein, fat or carbohydrate digested and virtually absorbed per 100 grams of the nutrient ingested as a component of the food or feed listed. The quantity digested and absorbed is taken as the quantity of the nutrient ingested minus the quantity subsequently found in the feces. Values for man are for food as commonly prepared for ingestion.

	Food- or Feedstuff	Man			Cattle[1]				Horse[1]				Chicken		
		Protein	Carbohydrate	Fat	Protein	Carbohydrate Fiber	Carbohydrate NFE[2]	Fat	Protein	Carbohydrate Fiber	Carbohydrate NFE[2]	Fat	Protein	Carbohydrate	Fat
1	Animal products[3]	97	98	95											
2	Bone meal				69			0					87	34	93
3	Buttermilk, dried				90			94	98				69	71	95
4	Eggs	97	98	95											
5	Fats			95											
6	Fish meal				88			95					75	35	83
7	Meat and fish	97		95											
8	Meat scrap				82			97					61	60	90
9	Milk, milk products	97	98	95	95			98	98						
10	Milk, skim, dried				90			93	100				75	66	57
11	Plant products[3]	85	97	90	70?	40?		76?	77?				76?	69?	80?
12	Barley				70			88	63	88	39	87	25	73	80	75
13	Corn, whole ground	60	96	90	63			88	83	69		89	59	86	94	90
14	Cottonseed meal				81	57	80	92	85	29	49	90	70	36	97
15	Macaroni, spaghetti	86	98	90									78	97	85
16	Oatmeal, rolled oats	76	98	90	90	80	98	96							
17	Oats, whole grain				74			76	84	79	44	79	80	56	66	92
18	Rice, white	84	99	90											
19	Soybean oil meal[4]				90	57	91	38							
20	Wheat, 85-93% extraction	83	94	90										74	34	79
21	Wheat bran				76	30	76	74	73	22	53	27		100	95	100
22	Fruit	85	90	90										59	37	86
23	Potatoes	74	96	90	55		91	1	63	75	101	42				
24	Sugar		98				97		70	32	83	50				
	Green roughages															
25	Kentucky bluegrass				71	70	64	51								
26	Pasture grass, mixed				75	74	77	42	66	33	62					
27	Silage, corn				53	66	69	74								
28	Timothy				59	68	72	57								
	Dried roughages															
29	Alfalfa hay				71	44	70	34	74	39	68					
30	Alfalfa meal				73	45	67	21								
31	Clover hay				63	56	69	58	56	38	64	29		56	34	55
32	Timothy hay				46	58	57	46	43	43	53	13				

/1/ Digestibility of roughages is determined by feeding one roughage alone, while that of concentrates and grains is determined by difference, e.g., feeding the material in conjunction with a roughage the digestibility of which has been determined. /2/ Nitrogen-free extract. /3/ Variety not specified. /4/ Solvent extracted.

208. PATHWAYS OF CARBOHYDRATE DIGESTION AND ABSORPTION: MAN, LABORATORY MAMMALS

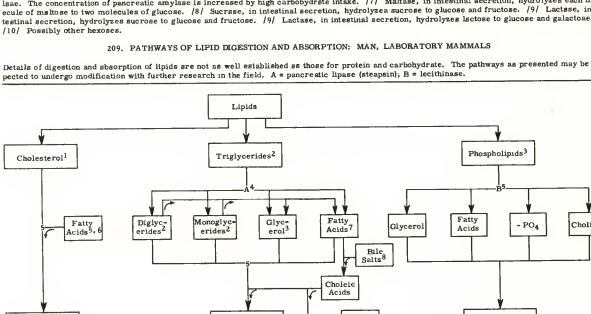
Carbohydrate digestion is the enzymatic hydrolysis of poly- and oligosaccharides into their monosaccharide components which are then absorbed into the blood stream. Monosaccharides are phosphorylated to hexose-6-PO_4[7] as they enter the intestinal mucosa and then dephosphorylated before they enter the blood stream. A = salivary amylase (ptyalin); B = pancreatic amylase (amylopsin); C = maltase; D = sucrase (invertase); E = lactase.



/1/ Ingested. /2/ Polysaccharides including glycogen, starch dextrins and cellulose are made up of many monosaccharide (simple sugar) molecules. Cellulose, although made up of glucose molecules is not digestible by mammals. /3/ Oligosaccharides are carbohydrates composed of only a few (down to two in the case of disaccharides) molecules of monosaccharide. Sucrose contains glucose and fructose; maltose is composed of two molecules of glucose; and lactose contains glucose and galactose as constituents. /4/ Ingested monosaccharides are absorbed into the blood stream without breakdown. /5/ Salivary amylase not only converts polysaccharides to soluble starch, etc., but also breaks off some maltose. /6/ Pancreatic amylase hydrolyzes starches, dextrins and glycogen to maltose; uncooked starch is hydrolyzed to some degree by pancreatic but not by salivary amylase. The concentration of pancreatic amylase is increased by high carbohydrate intake. /7/ Maltase, in intestinal secretion, hydrolyses each molecule of maltose to two molecules of glucose. /8/ Sucrase, in intestinal secretion, hydrolyzes sucrose to glucose and fructose. /9/ Lactase, in intestinal secretion, hydrolyses lactose to glucose and galactose. /10/ Possibly other hexoses.

209. PATHWAYS OF LIPID DIGESTION AND ABSORPTION: MAN, LABORATORY MAMMALS

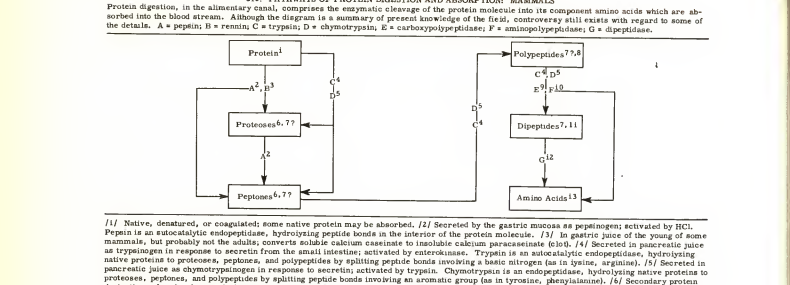
Details of digestion and absorption of lipids are not as well established as those for protein and carbohydrate. The pathways as presented may be expected to undergo modification with further research in the field. A = pancreatic lipase (steapsin); B = lecithinase.



/1/ Absorbed in the presence of fat (except in rabbits); excess cholesterol may hinder fat absorption. Some conversion to coprosterol by intestinal bacteria and excreted as such. Plant sterols are not absorbed(?). /2/ Tri-, di-, and monoglycerides = compounds of glycerol and 3 or 2 or 1 molecule fatty acid. Some absorption(?). /3/ Absorbed. Include (a) lecithins (= glycerol + fatty acids + phosphoric acid + choline) although there is some question whether unchanged lecithin can be absorbed, (b) cephalin (= glycerol + fatty acids + phosphoric acid + cholamine or serine, or inositol); (c) sphingomyelins (= fatty acid + phosphoric acid + choline + sphingosine). /4/ Lipolytic enzyme activated in intestinal lumen by bile salts, soaps, and certain proteins and amino acids. /5/ In succus entericus from intestinal mucosa. /6/ From hydrolysis of glycerides or phospholipids. /7/ Short-chain (i.e., 10 carbon or less) fatty acids, being water soluble, are readily absorbed into the intestinal mucosa; long chain fatty acids absorbed with the aid of bile salts (q.v.). /8/ In addition to forming cholesterol acid complexes with fatty acids, bile salts serve as emulsifying agent to hasten absorption of lipid digestion end products. /9/ Absorbed into lymphatic system. /10/ Mono- and diglycerides and fatty acids (from triglyceride or phospholipid hydrolysis) combine in the intestinal mucosa with endogenous glycerol (from dihydroxyacetone) to form triglycerides of different composition from those ingested. Those containing short-chain fatty acids are absorbed chiefly into the portal blood stream; the more insoluble fats containing long-chain fatty acids are absorbed through the lacteals into the lymphatic system. /11/ Formed in intestinal mucosa and absorbed into lymph and portal blood.

210. PATHWAYS OF PROTEIN DIGESTION AND ABSORPTION: MAMMALS

Protein digestion, in the alimentary canal, comprises the enzymatic cleavage of the protein molecule into its component amino acids which are absorbed into the blood stream. Although the diagram is a summary of present knowledge of the field, controversy still exists with regard to some of the details. A = pepsin; B = rennin; C = trypsin; D = chymotrypsin; E = carboxypolypeptidase; F = aminopolypeptidase; G = dipeptidase.



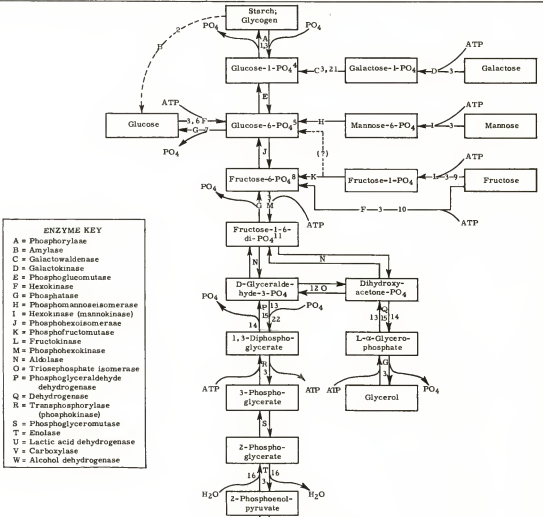
/1/ Native, denatured, or coagulated; some native protein may be absorbed. /2/ Secreted by the gastric mucosa as pepsinogen; activated by HCl. Pepsin is an autocatalytic endopeptidase, hydrolyzing peptide bonds in the interior of the protein molecule. /3/ In gastric juice of the young of some mammals, but probably not the adults; converts soluble calcium caseinate to insoluble calcium paracaseinate (clot). /4/ Secreted in pancreatic juice as trypsinogen in response to secretin from the small intestine; activated by enterokinase. Trypsin is an autocatalytic endopeptidase, hydrolyzing native proteins to proteoses, peptones, and polypeptides by splitting peptide bonds involving a basic nitrogen (as in lysine, arginine). /5/ Secreted in pancreatic juice as chymotrypsinogen in response to secretin; activated by trypsin. Chymotrypsin is an endopeptidase, hydrolyzing native proteins to proteoses, peptones, and polypeptides by splitting peptide bonds involving an aromatic group (as in tyrosine, phenylalanine). /6/ Secondary protein derivatives of molecular weight less than 1000, exclusive of polypeptides and simpler degradation products. /7/ Some absorption. /8/ A compound containing more than two amino acids joined by peptide linkages. /9/ An exopeptidase in pancreatic juice removing successively amino acids with free carboxyl groups from the end of the peptide chain, thus hydrolyzing polypeptides to simpler peptides and amino acids. /10/ Secreted by intestinal mucosa in succus entericus in response to enterocrinin, secretin, and presence of food; an exopeptidase, removing amino acids with free amino groups from the end of the peptide chain, thus hydrolyzing polypeptides to simpler peptides and amino acids. /11/ Dipeptides contain two amino acids. /12/ Secreted by intestinal mucosa in succus entericus; hydrolyzes dipeptides to amino acids by breaking the peptide linkage. /13/ Absorbed by intestinal mucosa; probably a stereochemical mechanism favoring absorption of L-amino acids.

211. PATHWAYS OF AMINO ACID METABOLISM

	Amino Acid	Product of Oxidative Deamination or Transamination	Product of Decarboxylation	Pathways and Products of Metabolism[1]
1	L-Alanine	Pyruvic acid		
2	L-Arginine	α-Keto-δ-guanidovaleric acid	Agmatine	Arginine → ornithine + urea; arginine → citrulline + NH_3.
3	L-Asparagine	α-Ketosuccinamic acid		Asparagine ⇌ aspartic acid + NH_3; α-ketosuccinamic acid → NH_3 + oxalacetic acid.
4	L-Aspartic acid	Oxalacetic acid	α-Alanine, β-alanine	Aspartic acid + carbamyl phosphate → $PO_4^{\ddagger}$ + carbamyl aspartic → pyrimidines; aspartic acid ⇌ (a) fumaric acid + NH_3, (b) homoserine ⇌ threonine.
5	L-Citrulline	α-Keto-δ-carbamido-valeric acid		Citrulline + aspartic acid + ATP → ADP + $PO_4^{\ddagger}$ + argininosuccinic acid ⇌ arginine + fumaric acid; citrulline + $PO_4^{\ddagger}$ ⇌ ornithine + carbamyl phosphate; carbamyl phosphate + ADP ⇌ CO_2 + NH_3 + ATP.
6	L-Cysteine & L-cystine	β-Mercaptopyruvic acid		β-Mercaptopyruvic acid → pyruvic acid + S_i cysteine → H_2S + NH_3 + pyruvic acid; cysteine → cysteine sulfenic acid → cysteine sulfinic acid → (a) cysteic acid → taurine, (b) hypotaurine, (c) via transamination → β-sulfinylpyruvate → pyruvate + SO_3 ↑ 2 cysteine ⇌ cystine.
7	L-Glutamic acid	α-Ketoglutaric acid	γ-Aminobutyric acid	See ornithine, proline, histidine, glutamine.
8	L-Glutamine	α-Ketoglutaramic acid		Glutamine ⇌ glutamic acid + NH_3; α-ketoglutaramic acid → NH_3 + α-ketoglutaric acid.
9	Glycine	Glyoxylic acid		Glycine + 1 carbon fragment (CH_2O or HCOOH) ⇌ serine; glyoxylic acid → formate + CO_2.
10	L-Histidine	β-Imidazolepyruvic acid	Histamine	Histidine → (a) urocanic acid → glutamic acid + NH_3 + formate, (b) carnosine, (c) anserine; histamine → imidazole acetic acid → NH_3 + formyl aspartic acid.
11	L-Hydroxy-proline	α-Keto-γ-hydroxy-δ-aminovaleric acid		See proline.
12	L-Isoleucine	α-α-Keto-β-methyl-valeric acid		α-Keto-β-methylvaleric acid → CO_2 + α-methylbutyryl CoA ⇌ tiglyl CoA ⇌ α-methyl-β-hydroxybutyryl CoA ⇌ α-methyl acetoacetyl CoA ⇌ acetyl CoA + propionyl CoA.
13	L-Leucine	α-Ketoisocaproic acid		α-Ketoisocaproic acid → CO_2 + isovaleryl CoA ⇌ seneciol CoA ⇌ β-hydroxyisovaleryl CoA ⇌ + CO_2 ⇌ β-hydroxy, β-methyl glutaryl CoA ⇌ acetoacetic acid + acetyl CoA.
14	L-Lysine	α-Keto-ε-aminocaproic acid	Cadaverine	Lysine → α-aminoadipic acid → α-ketoadipic acid → glutaric acid; α-keto-ε-aminocaproic acid → dihydropicolinic acid → pipecolic acid.
15	L-Methionine	α-Keto-γ-methiolbutyric acid		Methionine → labile CH_3 + homocysteine → (a) homocysteic acid, (b) H_2S + NH_3 + α-ketobutyric acid, (c) + serine → cystathionine → cysteine + homoserine → α-ketobutyric acid.
16	L-Ornithine	Glutamic-γ-semialdehyde or α-keto-δ-aminovaleric acid]	Putrescine	Ornithine ⇌ (a) proline, (b) glutamic acid; see citrulline.
17	L-Phenyl-alanine	Phenylpyruvic acid	Phenylethyl-amine	Phenylalanine → (a) tyrosine, (b) phenylpyruvic acid → phenylacetic and phenyllactic acids.
18	L-Proline	Glutamic-γ-semialdehyde or α-keto-δ-aminovaleric acid]	.....	Proline ⇌ (a) ornithine, (b) glutamic acid, (c) → hydroxyproline.
19	L-Serine	β-Hydroxypyruvic acid	Ethanolamine	Serine → NH_3 + H_2O + pyruvic acid; serine + indole ⇌ tryptophan; see glycine.
20	L-Threonine	α-α-Keto-β-hydroxy-butyric acid		Threonine → (a) NH_3 + H_2O + α-ketobutyric acid, (b) glycine + acetaldehyde; see aspartic acid.
21	L-Tryptophan	β-Indolepyruvic acid	Tryptamine	Tryptophan → formylkynurenine → formate + kynurenine → (a) kynurenic acid, (b) anthranilic acid + alanine, (c) 3-hydroxykynurenine → 3-hydroxyanthranilic acid → nicotinic acid.
22	L-Tyrosine	p-Hydroxyphenylpyruvic acid	Tyramine	p-Hydroxyphenylpyruvic acid → 2, 5-dihydroxyphenylpyruvic acid → CO_2 + homogentesic acid → fumarylacetoacetic acid → fumaric acid + acetoacetic acid.
23	L-Valine	α-Ketoisovaleric acid		α-Ketoisovaleric acid → CO_2 ↑ isobutyryl CoA ⇌ methacrylyl CoA ⇌ β-hydroxybutyryl CoA → CO_2 + propionyl CoA.

/1/ ADP = adenosine diphosphate; ATP = adenosine triphosphate; CoA = coenzyme A.

The pathway from stored or ingested carbohydrate to pyruvate is one of release of stored energy by anaerobic oxidation (glycolysis). Released energy is partly dissipated as heat and partly stored (temporarily) in the labile energy pool as "high energy phosphate" ($\sim PO_4$) by combination of $\sim PO_4$ with continuously available ADP (adenosine diphosphate) to form ATP (adenosine triphosphate). In the conversion of 1 mole of glucose(180 g), or of other monosaccharide to 2 moles of pyruvate (174 g), 2 moles of ATP are converted to ADP and 4 moles are formed from ADP, making a net gain of 2 moles of ATP, or approximately 20 kilocalories of readily available energy. If glucose-6-PO_4 has come from metabolic breakdown of glycogen, the cost is only 1 mole of ATP, making a net gain of 3 moles of ATP (approximately 30 kilocalories). The ATP is an immediate source of energy whose utilization(e.g., for muscular activity)is independent of oxygen supply. Aerobic oxidation (to carbon dioxide and water) begins where the present pathway ends and yields an additional 650 kilocalories per mole of hexose.

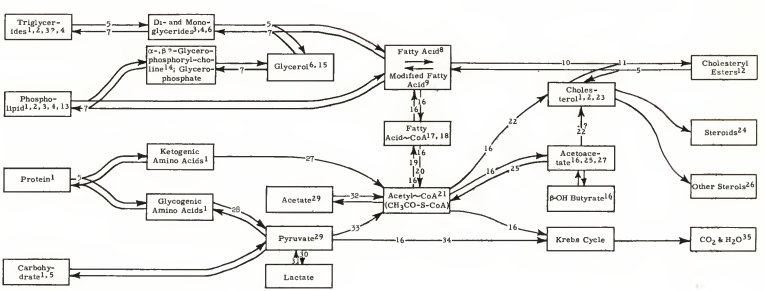


ENZYME KEY

A = Phosphorylase
B = Amylase
C = Galactowaldenase
D = Galactokinase
E = Phosphoglucomutase
F = Hexokinase
G = Phosphatase
H = Phosphomannoseisomerase
I = Hexokinase (mannokinase)
J = Phosphohexoisomerase
K = Phosphofructomutase
L = Fructokinase
M = Phosphohexokinase
N = Aldolase
O = Triosephosphate isomerase
P = Phosphoglyceraldehyde dehydrogenase
Q = Dehydrogenase
R = Transphosphorylase (phosphokinase)
S = Phosphoglyceromutase
T = Enolase
U = Lactic acid dehydrogenase
V = Carboxylase
W = Alcohol dehydrogenase

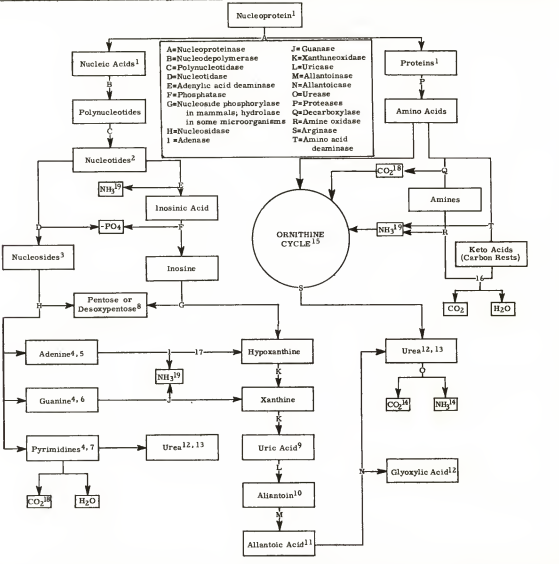
/1/ Adenylic acid and PO_4 required for activity in either direction. /2/ Digestion; glycogen and/or starch hydrolyzed to glucose in intestinal lumen. /3/ Mg^{++} required for this reaction. /4/ "Cori Ester." /5/ "Robison Ester." /6/ "Hexokinase reaction," assumed to be inhibited by growth hormone plus adrenal cortex hormone; and inhibition by these substances blocked by insulin, which thus favors conversion of glucose to glucose-6-phosphate. /7/ The reaction, glycogen to glucose-6-PO_4 to blood glucose, takes place in liver only; conversion of glucose to glucose-6-PO_4 to glycogen takes place in liver, muscle, and other tissues. /8/ "Neuberg Ester." /9/ In liver and muscle. /10/ In all tissue. /11/ "Harden-Young Ester." /12/ This reaction (to left) causes each step in the conversion to pyruvate to be doubled quantitatively; thus 1 mole of glucose gives rise to 2 moles of pyruvate. /13/ Hydrogen ions released. /14/ Hydrogen enters into the reaction. /15/ DPN acts as acceptor of released hydrogen ions, becoming DPNH in oxidative direction of the reaction; DPNH gives up hydrogen ions, becomes DPN, in reverse direction. Hydrogen ions accepted by DPN passed on in turn, to flavoprotein, cytochrome-c, cytochrome oxidase, molecular O_2. If molecular O_2 not sufficiently available, hydrogen ions may be passed from DPNH to pyruvate forming lactate. /16/ Inhibited by fluoride. /17/ K^+ also required. /18/ Thiamine pyrophosphate is required as coenzyme. /19/ Pyruvate, followed by conversion to lactate when oxygen supply is deficient (cf Fn 15), ends glycolysis in animal tissues. If oxygen is available pyruvate is oxidized via the Krebs Cycle, q.v. /20/ End of fermentation plant tissue. /21/ Uridine diphosphate glucose required as coenzyme. /22/ Inhibited by iodoacetate.

These pathways are believed to occur in the lipid metabolism of animal forms in general. They are based on studies confined chiefly to mammals.



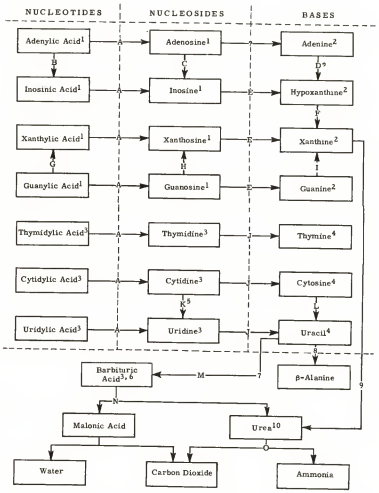
/1/ In intestinal lumen, blood, liver, other tissues. /2/ In chyle. /3/ Some absorption by intestinal mucosa. /4/ Formed in intestinal mucosa, or absorbed from lumen, pass into chyle, short chains possibly also into portal blood. /5/ Digestion in intestinal lumen. /6/ Probably transitory in tissues. /7/ In intestinal mucosa, liver, other tissues. /8/ Occur free (ionized) in intestinal lumen, blood, liver; free existence in chyle, questioned; free existence probably transitory in other tissues, if it occurs. /9/ In liver, carbon chains lengthened or shortened (cf Fn 20), and H added to C_{9-10}, or removed creating double bonds. /10/ Chiefly (?) unsaturated. /11/ Synthesis probably in intestinal mucosa, liver, blood. /12/ In chyle, blood, and small amounts in liver, other tissues; not in brain, red cells. /13/ Chiefly lecithin, cephalins (phosphatides of ethanolamine, serine, inositol, acetal, and polyglyceride phosphatides) some sphingomyelin. /14/ In intestinal mucosa, liver (?), other tissues (?). Split to choline, glycerol, phosphoric acid. /15/ In intestinal lumen, absorbed by intestinal mucosa, where resynthesized into glycerides, including phospholipids. Metabolized to pyruvate. /16/ In liver, other tissues. /17/ Fatty acid ester of coenszyme A, i.e., acyl~CoA ester, formed by ATP-dependent acylation of CoA or by transfer of CoA from succinyl- or other CoA ester. /18/ Coenszyme A probably = pantetheine (pantothenic acid + β-alanine + thioethanolamine) + ADP, with a third PO_4 at C_3 of the ribose; forms fatty acid thiol esters via the SH in the thioethanolamine. /19/ Reverse of β-oxidation (cf Fn 20). Retarded or blocked in diabetes mellitus, starvation (?). Insulin useful, probably necessary, but site of lipogenic action not known -- possibly the hexokinase reaction in carbohydrate metabolism. /20/ Fatty acid-CoA ester shortened 2 carbons at a time by β-oxidation, breaking off a molecule of acetyl~CoA at each step, and re-esterifying the remainder with CoA. /21/ Acetic acid ester of coenszyme A known also as S-acetyl coenszyme A, active acetyl. /22/ Via squalene (?). /23/ Adrenal steroids (C_{11}oxy) promote synthesis (?). /24/ Hormones, bile acids. /25/ Acetyl~CoA → Acetoacetyl~CoA → Acetoacetate. Transported from liver via blood to other tissues, where oxidized, via acetyl~CoA and Krebs Cycle, to CO_2 and H_2O. Some conversion to acetone. /26/ Coprosterol, epicoprosterol excreted. /27/ Tyrosine, leucine, isoleucine also converted directly to acetoacetate. /28/ Aspartate enters Krebs Cycle not via pyruvate, but by conversion directly to oxalacetate. /29/ Occurs in blood, liver, muscle, other tissues. /30/ Occurs in muscle, especially in exercise, the lactate diffusing into the blood stream. /31/ Occurs in liver, muscle, brain, other tissues. /32/ ATP-dependent reaction with CoA. /33/ Diphosphothiamine (= cocarboxylase), lipoic acid, Mg^{++} required. /34/ Pyruvate + CO_2 → oxalacetate, malate, components of Krebs Cycle. Oxalacetate condenses with acetyl~CoA, to form citrate. This removal of acetyl~CoA by oxalacetate (i.e., by pyruvate), occurring when acetyl~CoA is being formed in active fat catabolism, may explain antiketogenic action of carbohydrate (and protein). /35/ And energy liberation.

Nucleoproteins generally are composed of basic proteins, histones or protamins, associated with nucleic acids. The nucleic acids are complex molecules, each composed of many nucleotide units, joined by phosphate sugar linkages. Each nucleotide is made up of a purine or pyrimidine base, linked to a pentose or desoxypentose, and this in turn to a molecule of phosphoric acid. Upon hydrolysis of the nucleotide in the digestive tract or tissues, the phosphoric acid is removed. The remaining compound, a nucleoside, contains the purine or pyrimidine base and the sugar residue.



/1/ Catabolism of nucleoprotein, nucleic acid, and protein may take place in the alimentary canal or in the tissues. See Table 251 for detailed pathways of purine and pyrimidine nucleotide catabolism. /2/ Some intestinal absorption. Nucleotidase in liver splits both pyrimidine and purine nucleotides to nucleosides. /3/ Absorbed in the intestine. Purine nucleosides are split into purines and pentoses by purine nucleosidase present in tissues. /4/ Mammals do not require exogenous purines or pyrimidines, but can synthesize them from products of protein metabolism. /5/ Adenine and guanine are the only naturally occurring purines in nucleic acids. /6/ Excreted by pig and spider. /7/ Little is known about the stages in pyrimidine catabolism. It is thought that pyrimidine nitrogen is largely converted to urea, indicating disruption and metabolism of the pyrimidine ring. /8/ d-ribose and d-2-deoxyribose have been definitely established as present in nucleoproteins, and are degraded via the Warburg-Dickens-Lipmann pathway; other pentoses may be present. /9/ Excreted as end product of purine catabolism by primates, Dalmation dog, some reptiles, some insects, and as end product of catabolism of proteins as well as purines and pyrimidines by birds (no urea formation by birds). /10/ Excreted by most mammals, gastropods, and some insects. /11/ Excreted by some teleost fishes. /12/ Excreted by most fishes, amphibia, fresh-water lamellibranches. /13/ Urea is excreted as the end product of amino acid metabolism by mammals, and as an end product of purine (and pyrimidine?) metabolism by some other forms. /14/ Crustacea, gephyrean worms, marine lamellibranchs do not excrete urea but break it down to CO_2 and NH_3 which are excreted. /15/ Urea formation in the mammalian liver is via the "Ornithine Cycle" (Krebs-Henseleit Cycle). The pathway through the cycle is: ornithine ⟶ citrulline ⟶ arginine succinate ⟶ arginine ⟶ ornithine. CO_2 and NH_3 enter the cycle via carbamyl glutamic acid at ornithine; NH_3 enters the cycle via aspartic acid at citrulline. Arginine succinate is split to arginine and fumaric acid, after which arginine is converted to ornithine with the release of urea. /16/ Via Krebs Cycle. In the course of amino acid metabolism, previous to entry into the Krebs Cycle, sulfur-containing amino acids lose their sulfur -- usually in the form of SO_4. /17/ There is little likelihood that the route adenine ⟶ hypoxanthine is of any importance in animals. Adenase is not found to any extent in mammals. /18/ May enter into metabolic processes, into the Ornithine Cycle and be incorporated into and excreted as urea, or be excreted as such. /19/ NH_3, as in the case of CO_2, is also used to synthesize many tissue constituents. Hence, it may enter into metabolic processes, be built into amino acids, incorporated into urea and excreted, or excreted as such across the kidney tubule (in appropriate animal species).

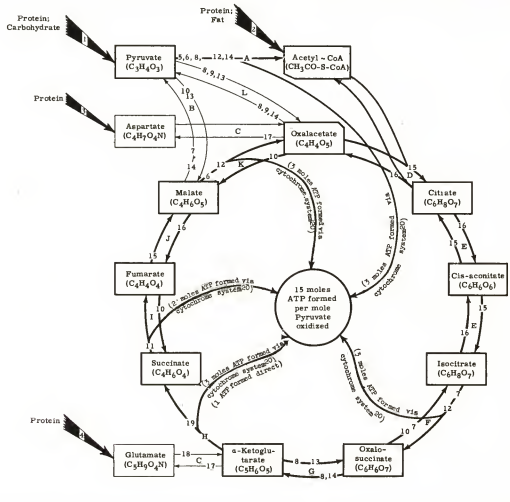
Nucleotides are composed of a purine or pyrimidine base linked to a pentose or desoxypentose sugar which, in turn, is linked to phosphate. Removal of the phosphate leaves a compound designated as a nucleoside. See Table 252 for pathways of nucleoprotein catabolism in general.
A = Phosphatase; B = Adenylic acid deaminase; C = Adenosine deaminase; D =Adenase(?);E = Nucleoside phosphorylase; F = Xanthine oxidase; G = Guanylic acid deaminase; H = Guanosine deaminase; I = Guanase; J = Phosphorylase or hydrolase; K = Cytidine deaminase; L = Cytosine deaminase; M = Uracil-thymine oxidase; N = Barbiturase; O = Urease.



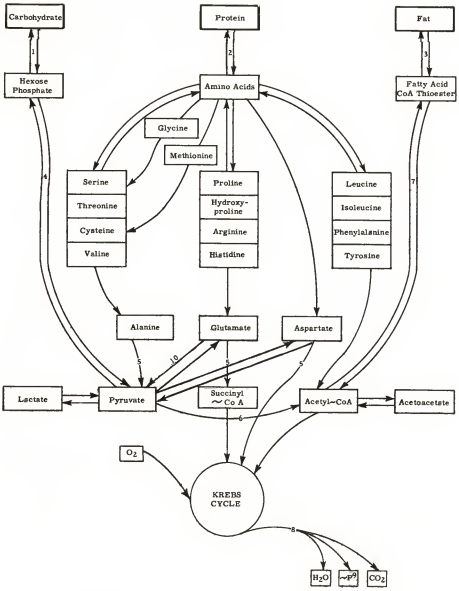
/1/ A purine derivative or contains purine ring. /2/ A purine. /3/ A pyrimidine derivative or contains pyrimidine ring. /4/ A pyrimidine. /5/ Demonstrated in yeast and Escherichia coli. /6/ Thymine yields 5-methyl barbituric acid. /7/ Pathway demonstraied with Corymebacterium and Mycobacterium. /8/ In animal tissues; methyl uracil (thymine) yields β-aminoisobutyric acid. /9/ Via: uric acid, allantoic acid, and glyoxylic acid. /10/ Urea is excreted as the end product of amino acid metabolism by mammals, and as an end product of purine and pyrimidine metabolism by most fishes, amphibia and fresh-water lamellibranches.

The Krebs Cycle (tricarboxylic acid cycle) is a major pathway for the final aerobic oxidation of carbohydrates, fats, and proteins. These three nutrients are channeled into the cycle via their two key metabolites, pyruvate and acetyl~CoA ("active acetate"). Each "revolution" of the cycle oxidizes acetate to CO_2 and H_2O. One mole (59 g) of acetate thus oxidized releases approximately 200 kilocalories of energy. A portion of the released energy (approximately 144 kilocalories) enters the phosphate pool as ATP. Twelve moles of ATP are formed from ADP and PO_4 (by energizing PO_4 to ~PO_4). The remainder of the released energy appears as heat. Oxidation of 1 mole (87 g) of pyruvate, proceeding via acetyl~CoA, contributes a total of 14 moles of ATP to the energy pool.

A=Pyruvic decarboxylase; B=Malic enzyme; C=Transaminase; D=Condensing enzyme; E= Aconitase; F=Isocitric dehydrogenase; G=Oxalosuccinic carboxylase; H= α-Ketoglutaric dehydrogenase; I=Succinic dehydrogenase; J=Fumarase; K=Malic dehydrogenase; L=Oxalacetic decarboxylase.

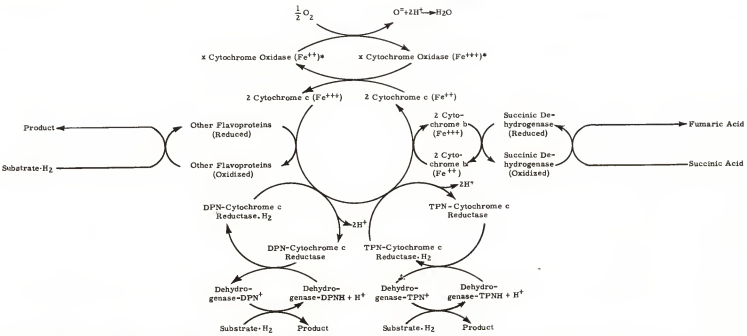


/1/ Glucogenic amino acid precursors for pyruvate are: alanine, glycine, serine, threonine, methionine, cysteine, valine. /2/ Ketogenic amino acid precursors for acetyl~CoA are: leucine, isoleucine, phenylalanine, tyrosine. /3/ Aspartic acid occurs as a component of protein. /4/ Glutamic acid occurs as a component of protein or may be formed from: arginine, proline, hydroxyproline, histidine, ornithine. /5/ Coenzyme-A (=ATP-pantoyl-β-alanyl-thioethanolamine) and α-lipoic acid required. /6/ In the oxidative direction, DPN (=diphosphopyridine nucleotide, a compound of nicotinamide, a-ribose, H_3PO_4 and adenine; also known as coenzyme I) acts as hydrogen acceptor; in the reverse direction $DPNH_2$ is hydrogen donor. /7/ In the oxidative direction, TPN (=triphosphopyridine nucleotide; coenzyme II) acts as hydrogen acceptor; in the reverse direction, $TPNH_2$ is hydrogen donor. /8/ DPT (=diphosphothiamine; thiamine pyrophosphate; cocarboxylase) required as coenzyme for the carboxylase (A); also Mg^{++}, or Mn^{++}, is required as activator for the enzyme. /9/ Biotin required as coenzyme for decarboxylation. /10/ 2H enters into the reaction. /11/ 2H released and their electrons transferred to cytochrome. /12/ Hydrogen ions transferred to DPN (or, in the case of isocitrate ~ oxalsuccinate, to TPN) and pass in turn to flavoprotein, cytochrome-c, cytochrome oxidase, and finally to combination with molecular oxygen. For each H thus passed and finally oxidized, 1.5 moles of ATP are formed by the addition of energized phosphate (~PO_4) to ADP. /13/ CO_2 enters into the reaction. /14/ CO_2 released. /15/ H_2O enters into the reaction. /16/ H_2O released. /17/ NH_3 enters into the reaction by transamination. /18/ NH_3 transferred from glutamate by transamination, then enters into Krebs Cycle via α-ketoglutarate. /19/ Footnotes 5,6,8,12, 14 apply to this reaction. /20/ For details, see table on cytochrome system.



/1/ Phosphorylase and PO_4 phosphorylate hexose units in stored polysaccharides; hexokinase and ATP phosphorylate hexoses. /2/ Proteolysis by proteases in digestive tract or tissues. Synthesis by proteases of tissues. /3/ Lipase splits fat into fatty acids and glycerol; glycerol, via glycerol phosphate and dihydroxyacetone phosphate, enters the glycolytic cycle. Fatty acid then is acted upon by coenzyme A. /4/ Glycolysis. /5/ Oxidative deamination. /6/ Oxidative decarboxylation. /7/ β-oxidation. /8/ Chain of electron-transmitting enzymes. /9/ "High energy" phosphorus. /10/ Transamination.

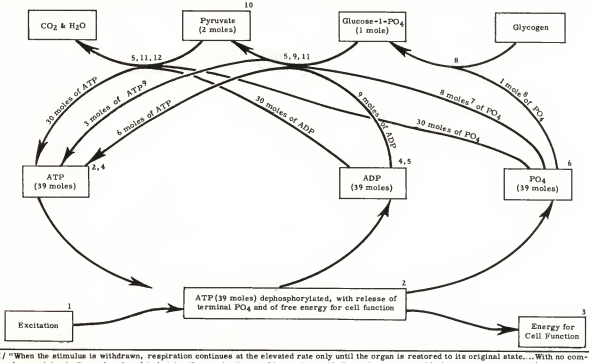
The cytochromes (iron-containing compounds) in association with certain other compounds constitute the "Cytochrome System." The system operates as the final pathway by which an intermediate metabolite ("substrate"), under the influence of its specific dehydrogenase, releases hydrogen to the first member in a series of carriers for ultimate combination with oxygen to form water. Each step in the process involves both oxidation and reduction: The cytochrome system oxidizes the hydrogen of the substrate by removing electrons from it, thereby producing oxidized substrate and hydrogen ions, and the system itself is reduced in the process and is finally oxidized by molecular oxygen. For each gram of hydrogen thus passed and finally oxidized enough energy is produced to form 1.5 moles of ATP from ADP and PO_4.



*Cytochrome a and cytochrome a_3 have not been proved to be separate enzymes. For the present, therefore, there is only one enzyme that acts between cytochrome c and molecular oxygen. This component is termed cytochrome oxidase.

219. PATHWAYS OF ENERGY METABOLISM: MUSCLE

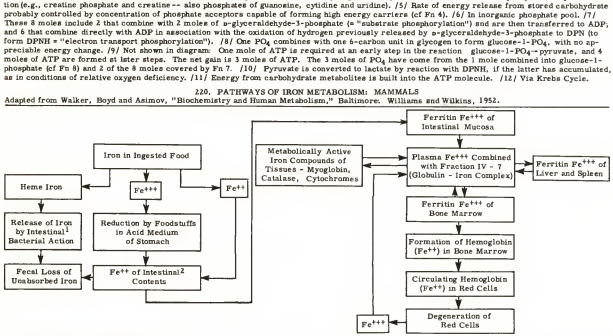
Excitation of the muscle (cell) is accompanied by reversal of polarity of the cell membrane. The first identifiable metabolic event to follow is dephosphorylation of ATP. The breaking off of the terminal PO_4 of ATP is accompanied by release of energy previously stored in the molecule. The compound, minus one phosphate, is left as ADP. This compound can accept phosphate and again form ATP. If the presence of such acceptor is viewed as the stimulus to the subsequent steps in activity-metabolism, the presence of ADP causes progression of glucose-1-PO_4 to pyruvate (or to lactate if DPNH has accumulated as a result of O_2 inadequacy), and also brings about the progression of pyruvate to CO_2 and H_2O. In so doing, ADP is reconverted to ATP, (and other phosphate-acceptors that may be present are similarly rephosphorylated). The stimulus to extra release of energy from carbohydrate stores thus disappears, and the cell returns to its basal state of respiration and energy release.



/1/ "When the stimulus is withdrawn, respiration continues at the elevated rate only until the organ is restored to its original state....With no compounds remaining in the unphosphorylated state, the respiration mechinery stops with the various enzymes blocked in the acylated and/or phosphorylated states." /2/ The quantity of ATP assumed, 39 moles, is adjusted to the catabolism of 1 mole of glucose-1-PO_4 or 1 mole of 6-carbon unit, component of glycogen. /3/ Approximately 10 kilocalories (a compromise figure; values of 7-12 have been reported recently) of free energy per mole of ATP converted to ADP, or about 400 kilocalories for the quantities represented in the diagram. Energy used for muscle contraction, and for synthesis. /4/ Other high energy carriers than ATP (adenosine triphosphate) and other phosphate acceptors than ADP (adenosine diphosphate) may also function (e.g., creatine phosphate and creatine -- also phosphates of guanosine, cytidine and uridine). /5/ Rate of energy release from stored carbohydrate probably controlled by concentration of phosphate acceptors capable of forming high energy carriers (cf Fn 4). /6/ In inorganic phosphate pool. /7/ These 8 moles include 2 that combine with 2 moles of 2-glyceraldehyde-3-phosphate (a "substrate phosphorylation") and are then transferred to ADP; and 6 that combine directly with ADP in association with the oxidation of hydrogen previously released by 2-glyceraldehyde-3-phosphate to DPN (to form DPNH = "electron transport phosphorylation"). /8/ One PO_4 combines with one 6-carbon unit in glycogen to form glucose-1-PO_4, with no appreciable energy change. /9/ Not shown in diagram. One mole of ATP is required at an early step in the reaction glucose-1-PO_4 $\rightarrow$ pyruvate, and 4 moles of ATP are formed at later steps. The net gain is 3 moles of ATP. The 3 moles of PO_4 have come from the 1 mole combined into glucose-1-phosphate (cf Fn 8) and 2 of the 8 moles covered by Fn 7. /10/ Pyruvate is converted to lactate by reaction with DPNH, if the latter has accumulated, as in conditions of relative oxygen deficiency. /11/ Energy from carbohydrate metabolites is built into the ATP molecule. /12/ Via Krebs Cycle.

220. PATHWAYS OF IRON METABOLISM: MAMMALS

Adapted from Walker, Boyd and Asimov, "Biochemistry and Human Metabolism," Baltimore: Williams and Wilkins, 1952.

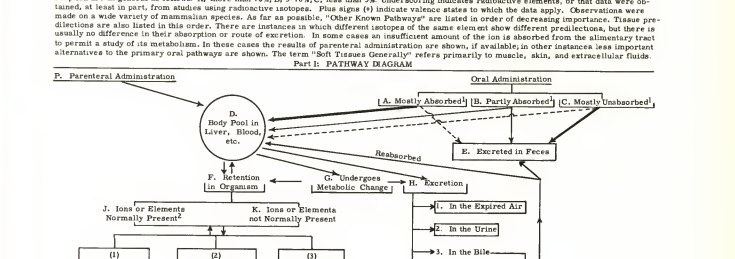


/1/ Large intestine. /2/ Small intestine.

221. PATHWAYS OF MINERAL METABOLISM: MAMMALS

The system of letters and numbers used in this table traces the course(s) of various ions through the diagram. The classifications as to extent of absorption are in general as follows: A, more than 70%; B, 5-70%; C, less than 5%. Underscoring indicates radioactive elements, or that data were obtained, at least in part, from studies using radioactive isotopes. Plus signs (+) indicate valence states to which the data apply. Observations were made on a wide variety of mammalian species. As far as possible, "Other Known Pathways" are listed in order of decreasing importance. Tissue predilections are also listed in this order. There are instances in which different isotopes of the same element show different predilections, but there is usually no difference in their absorption or route of excretion. In some cases an insufficient amount of the ion is absorbed from the alimentary tract to permit a study of its metabolism. In these cases the results of parenteral administration are shown, if available; in other instances less important alternatives to the primary oral pathways are shown. The term "Soft Tissues Generally" refers primarily to muscle, skin, and extracellular fluids.

Part I: PATHWAY DIAGRAM



/1/ This classification is obviously rather arbitrary, since extent of absorption may depend on the amount offered; for example, the absorption of physiologically essential elements may be nearly complete when fed at or near the level of minimum requirement. It is assumed that the various ions are offered in the form of simple soluble compounds, or metallic oxides. /2/ This group includes some trace elements with no known function. /3/ Other than in the bile, or by route not definitely established.

Part II: INDIVIDUAL CATIONS

Information inadequate for classification, but probably poorly absorbed[1]: actinium, berkelium, californium, iridium, osmium, rare earth elements not mentioned below, rhodium, tantalum, and technetium.

	Element	Primary (Oral) Pathways[2]	Other Known Pathways
1	Aluminum	CE	PDH2, PDH3, PDF2(2)
2	Americium	CE	PDH4, PDFK(2, 1), PDH2
3	Antimony^{+++}	BE, BDH2	PDFK(2, 3), PDH4
4	Arsenic^{+++}	BE, BDH2	BDFK(2, 3), BDH4
5	Barium	BE, BDH4	BDFK(1), BDH2
6	Beryllium	CE	PDFK(3, 2, 1), PDH2, PDH4
7	Bismuth^{+++}	CE	PDH2, PDFK(1, 2, 3), PDH4
8	Cadmium	CE	PDFK(2), PDH4, PDH2
9	Calcium	BE, BDFJ(1)	BDH3, BDH4, BDH2, BDFJ(3)
10	Cerium	CE	PDH3, PDH4, PDFK(1, 2)
11	Cesium	ADH2	ADH3, ADH4, ADFJ(1)
12	Cobalt^{++}	BE, BDH2	BDH3, BDH4, BDFJ(2)
13	Copper^{++}	BE, BDH2	BDH3, BDFJ(2)
14	Curium	Probably CE[2]	PDFK(1, 2), PDH4, PDH2
15	Francium	Probably ADH2[2]	PDFK(2, 3)
16	Gallium	CE	PDH2, PDFK(1, 2), PDH4
17	Germanium	ADH2	ADH4
18	Gold^{+++}	CE	PDFK(2), PDH2, PDH4
19	Indium	ADH2	
20	Iron^{++}	CE	PDH4, PDFJ(2)
21	Lanthanum	CE	PDH2, PDH3, PDFK(2, 1)
22	Lead^{++}	BE, BDH3	PDFK(1, 2), PDH2
23	Lithium	ADH2	ADH4, ADFJ(3, 1)
24	Magnesium	BE, BDH2	BDH3, BDFJ(1, 2, 3)
25	Manganese^{++}	CE	PDH3, PDH4, PDFJ(2, 3)
26	Mercury^{++}	BE, BDH2	BDFK(2, 3), BDH3, BDH4
27	Neodymium	Probably CE[2]	PDH4, PDFK(2, 1)
28	Neptunium	CE	PDFK(1)
29	Nickel^{++}	BE, BDH2	BDH4, BDFJ(2)
30	Niobium	CE	PDH2, PDFK(3)
31	Palladium	Probably CE[2]	PDH2, PDFK(2, 1), PDH4
32	Platinum	Probably CE[2]	PDH2, PDFK(2), PDH4
33	Plutonium	CE	PDFK(1, 2), PDH4, PDH2
34	Polonium	CE	PDFK(2, 1, 3), PDH4, PDH2
35	Potassium	ADH2	ADFJ(3, 2), ADH3, ADH4
36	Praesodymium	CE	PDFK(1, 2), PDH3, PDH4
37	Promethium	CE	PDFK(1, 2), PDH3, PDH4
38	Protactinium	Probably CE[2]	PDFK(1)
39	Radium D	Probably BE, BDH2[2]	PDH2, PDH4, PDFK(1)
40	Radium	BE, BDFK(1, 2)	BDH4, BDH2
41	Rubidium	ADH2	ADFJ(3, 2), ADH3
42	Ruthenium	CE	PDFK(2)
43	Samarium	CE	PDFK(1, 2), PDH3
44	Scandium	Probably CE[2]	CDH2, CDFJ(1, 3)
45	Selenium^{++++}	ADH2	ADGH1, ADFK(2, 3)
46	Silver	CE	PDH3, PDFK(2, 3), PDH2, CDGFK[4]
47	Sodium	ADH2	ADFJ(3, 1, 2), ADH3, ADH4
48	Strontium	BE, BDFK(1)	BDH2, BDH4
49	Tellurium^{++++}	BE, BDGH2	BDGH3, BDGH1, BDGFK(2)
50	Thallium^{+}	ADH2	ADH4, ADFK(2, 3)
51	Thalium	CE	PDFK(1, 2), PDH2
52	Tin^{++}	BE, BDH2	BDFJ(2, 3), BDH4
53	Titanium	Probably CE[2]	CDFJ(2)
54	Uranium^{+++++}	BE, BDH2	BDFK(2, 1)
55	Yttrium	CE	PDFK(1, 2), PDH2, PDH4
56	Zinc	CE	CDFJ(2, 3), CDH3, CDH4, CDH2
57	Zirconium	CE	PDFK(1)

/1/ As would be judged from its position in the periodic table, or on solubility at neutral pH values. /2/ Cations absorbed orally may be assumed to follow the same pathways when given parenterally. /3/ Administered as a soluble complex. /4/ Skin.

Part III: INDIVIDUAL ANIONS

Information inadequate for classification: cyanate, ferricyanide, periodate.

	Element	Primary (Oral) Pathways[1]	Other Known Pathways
1	Bicarbonate	ADH1, ADH2, ADH3	ADH4, ADFJ(all tissues)
2	Borate	ADH2	
3	Bromate	ADH2	ADG(to bromide)
4	Bromide	ADH2	ADH3, ADH4, ADFK(3, 1, 2)
5	Chlorate	ADH2	
6	Chloride	ADH2	ADH3, ADH4, ADFJ(3, 1, 2)
7	Chromate	ADH2	ADH4, ADGH2, ADGH3, ADGFK(2)
8	Cyanide	ADH2	ADH1, ADG(to SCN^{-})
9	Ferrocyanide	ADH2	
10	Fluoride	ADH2	ADFJ(1, 3), ADH4
11	Hypophosphate	ADH2	
12	Iodate	ADG(to iodide)	
13	Iodide	ADH2	ADFJ(3, 2), ADH3
14	Molybdate	ADH2	ADH4, ADFJ(1, 2)
15	Nitrate	ADH2	ADG, ADFK(3)
16	Nitrite	ADG(to nitrate)	
17	Oxalate	ADH2	
18	Perchlorate	ADH2	
19	Permanganate	CE(reduced to MnO_2)	
20	Perrhenate	Probably CE[2]	PDH2, PDFK(2)
21	Persulfate	ADG(to sulfate)	
22	Phosphate	BE, BDH2	BDFJ(1, 2, 3)BDH3, BDH4
23	Silicate	BE, BDH2	BDFJ(2)
24	Sulfate	BE, BDH2	BDH3, BDH4
25	Sulfide	ADG(to sulfate)	ADH3
26	Thiocyanate	ADH2	ADFK(3), ADH3, ADH4
27	Thiosulfate	BE, BDG(to sulfate)	
28	Tungstate	BE, BDH2	BDFK(1, 2)
29	Vanadate	ADH2	ADFJ(2), ADH4

/1/ Anions absorbed orally may be assumed to follow the same pathways when given parenterally. /2/ As would be judged from its position in the periodic table, or on solubility at neutral pH values.

Values, widely variable with changes in diet, are based on "normal" dietary intake, including approximately 10 grams of nitrogen per day. Values are per kilogram of body weight per day and are expressed as milligrams unless otherwise noted. Values in parentheses are ranges and conform with estimate "d" of the 95% range (cf Introduction).

	Constituent	Excreted in Urine	Excreted in Feces
1	Water, total	17,000(7,800-27,500)	(910-1820)
2	Solids, total	860(780-1000)	394(140-560)
3	Nitrogen, total[1,2]	160(112-268)	24(11.4-36.0)
4	Protein nitrogen	(0.0046-0.018)	
5	Amino acid nitrogen	2.5(2.2-4.4)	
6	Ammonia nitrogen	9.2(4.0-18.2)	(0.36-1.2)
	Principal N-Containing Constituents		
7	Creatinine	15(12-25)	
8	Hippuric acid	8(1-12)	
9	Urea	300(215-500)	
10	Uric acid	9(5-12)	
	Amino Acids		
11	Alanine, total	0.55	
12	Arginine, free	0.31(0.15-0.5)	
13	Arginine, combined	0.1(0.0-0.2)	
14	Arginine, total	0.4(0.34-0.5)	3.8(2.9-5.0)
15	Aspartic acid, free	0.02(0.014-0.26)	
16	Aspartic acid, combined	2.3(1.2-3.7)	
17	Aspartic acid, total	2.32(0.37-3.7)	
18	Citrulline, free[3]	0.58(0.26-0.7)	
19	Citrulline, total	(0.345-0.79)	
20	Cystine, free	1.3(0.65-2.0)	
21	Cystine, total	(1.5-2.4)	
22	Glutamic acid, free	0.52(0.0-1.07)	
23	Glutamic acid, combined	4.5(1.0-10.0)	
24	Glutamic acid, total	5.27(1.58-11.55)	
25	Glycine, free	10.1(9.0-12.0)	
26	Glycine, total	(2.3-18.0)	
27	Histidine, free	2.7(0.94-4.8)	
28	Histidine, combined	0.6(0.07-1.8)	
29	Histidine, total	3.0(0.98-6.59)	1.7(1.4-2.1)
30	Hydroxyproline, total	0.02	
31	Isoleucine, free	0.085(0.03-0.3)	
32	Isoleucine, combined	0.2(0.06-0.4)	
33	Isoleucine, total	0.3(0.11-0.6)	4.3(3.3-5.5)
34	Leucine, free	0.14(0.05-0.25)	
35	Leucine, combined	0.2(0.05-0.4)	
36	Leucine, total	0.32(0.20-0.52)	5.6(4.3-6.9)
37	Lysine, free	0.5(0.25-1.13)	
38	Lysine, combined	0.6(0.2-1.1)	
39	Lysine, total	1.0(0.48-2.0)	5.7(4.5-6.9)
40	Methionine, free	0.11(0.05-0.18)	
41	Methionine, combined	0.03	
42	Methionine, total	0.14(0.12-0.17)	
43	Ornithine, free[3]	0.15	
44	Phenylalanine, free	0.23(0.1-0.43)	
45	Phenylalanine, combined	0.1(0.04-0.2)	
46	Phenylalanine, total	0.33(0.21-0.6)	
47	Proline, free	0.12(0.05-0.21)	
48	Proline, combined	0.5(0.3-0.8)	
49	Proline, total	0.61(0.33-0.9)	
50	Serine, free	0.4(0.21-0.52)	
51	Serine, combined	0.25(0.0-0.5)	
52	Serine, total	0.65(0.35-1.4)	
53	Threonine, free	0.37(0.17-0.62)	
54	Threonine, combined	0.4(0.3-0.8)	
55	Threonine, total	0.77(0.36-1.2)	4.0(3.3-5.2)
56	Tryptophan, free	0.37(0.12-0.7)	
57	Tryptophan, combined	0.3(0.09-0.4)	
58	Tryptophan, total	0.7(0.23-1.3)	
59	Tyrosine, free	0.3(0.17-0.55)	
60	Tyrosine, combined	0.5(0.08-0.9)	
61	Tyrosine, total	0.79(0.35-1.45)	
62	Valine, free	0.065(0.04-0.125)	
63	Valine, combined	0.2(0.09-0.4)	
64	Valine, total	0.3(0.21-0.45)	4.6(3.6-6.2)
	Electrolytes and Minor Minerals		
65	Aluminum, μg	(0.7-1.6)	0.6
66	Arsenic, μg	0.46(0.0-1.15)	33(1-116)
67	Bromine, μg	(12-110)	
68	Calcium, μg	2900(1100-4910)	7490(5,000-10,000)
69	Chloride	115(84-193)	(0.21-0.5)
70	Cobalt, μg	0.07(0.05-0.12)	0.007(0.002-0.02)
71	Copper, μg	2.38(0.0-7.52)	27(23-37)
72	Fluoride, μg	(6.7-100)[4]	
73	Iodide, μg	1.4(0.2-2.1)	
74	Iron, μg	0.7(0.7-1.4)	120(65-208)
75	Lead, μg	0.5(0.06-2.1)	4.2(2.2-19.8)
76	Magnesium, μg	1850(950-4500)	2500(1510-3185)
77	Manganese, μg	(0.095-1.4)	(18-120)
78	Mercury, μg	(0.007-0.01)	0.14
79	Nickel, μg	2.1(2.0-4.0)	(1.2-2.5)

	Constituent	Excreted in Urine	Excreted in Feces
	Electrolytes and Minor Minerals (concluded)		
80	Nitrates, μg	7(40	
81	Phosphorus	15(10-19)	9.86(7.1-20)
82	Potassium	54(14-66)	6.7
83	Selenium, μg	1.0(0.0-3.3)	
84	Silicon, μg	108(14-200)	
85	Silver, μg		0.8
86	Sodium	46(38-91)	1.7
87	Sulfur, total	1.6.5(4-40)	2.0
88	Sulfur, ethereal	1.0(0.4-4.3)	
89	Sulfur, inorganic	12.5(3.5-18.25)	
90	Sulfur, neutral	1.9(1.0-3.0)	
91	Tin, μg	(0.13-0.31)	(170-450)
92	Zinc, μg	18(11-33)	100(58-144)
	Hormones		
93	Androgens, μg	(30-100)	
94	Epinephrine, μg	0.16(0.07-0.31)	
95	Estrogens, μg	(0.1-0.5)	
96	Formaldehydogenic steroids, μg	(3-140)	
97	17-Ketosteroids, μg	♂ 160, ♀ 100	
98	Oxycorticosteroids, μg	(1.0-6.0)	
99	Noradrenaline, μg	0.4(0.18-0.9)	
	Lipids		
100	Cholesterol, total	(0.0-0.007)	8(10-20)[5]
101	Fat, total		56(30-100)
102	Fat, neutral		(10-45)
103	Fat, unsaponifiable		33(22-38)[6]
104	Fatty acids, total		30(4-64)
105	Fatty acids, free		16(4-38)
106	Soaps		53(40-66)[6]
	Organic Acids		
107	Citric acid	(85-17)	
108	Creatine[7]	2.9(1.1-3.86)	
109	Guanidoacetic acid	(0.23-0.51)	
110	Formic acid	(0.42-2.0)	
111	Indoleacetic acid	(0.03-0.06)	
112	Lactic acid	40	
113	Oxalic acid	0.285(0.23-0.5)	
114	Phenols	4.0(0.19-6.6)	(0.0-3.0)
	Pigments		
115	Bilirubin, μg	70	
116	Coproporphyrin I and III, μg	(0.24-1.4)	
117	Porphyrins, μg	(0.0-0.4)	
118	Urobilin, μg	(7-20)	
119	Urobilinogen, μg	(0.6-3.0)	2.0(0.57-4.0)
	Vitamins		
120	Vitamins A, D, K, μg	(0-trace)	
121	Ascorbic acid, μg	380(150-790)	70(60-70)
122	Biotin, μg	0.4(0.33-0.75)	1.9(0.63-6.64)
123	Carotenes, μg		(20-600)[8]
124	Choline, μg	90(80-130)	
125	Cobalamin, μg	0.0004(0.00023-0.00079)	
126	Vitamin E, μg		308(226-391)
127	Folic acid group, μg	0.2(0.03-0.3)	4.3(1.8-7.7)
128	Inositol, μg	170(170-220)	
129	Nicotinic acid, μg	(11-105)	52(12-124)
130	N-methyl nicotinamide, μg	130(73-400)	
131	Pantothenic acid, μg	44(20-100)	31.4(3.85-63.4)
132	Para-aminobenzoic acid, μg	2.11(2.0-3.0)	3.5(1.01-8.2)
133	Pyridoxal, μg	3.0(0.7-5.4)	
134	Pyridoxamine, μg	1.6(0.3-2.1)	
135	4-Pyridoxic acid, μg	(0.79-160)	
136	Riboflavin, μg	14.3(0.2-22.5)	14.7(8.0-23.0)
137	Thiamine, μg	2.6(0.43-5.6)	7.8(0.67-18.0)
138	Trigonelline, μg	(30-300)	
	Miscellaneous Compounds		
139	Acetone bodies	0.285(0.03-0.7)	
140	Allantoin	0.27(0.18-0.36)	
141	Histamine	(0.2-1.0)	
142	Hydroxytyramine, μg	(1.4-2.8)	
143	Imidazole derivatives	(1.35-9.4)	(0.0-0.2)
144	Indican	0.14(0.06-0.45)	
145	Methionine sulfoxide	(0.0-0.31)	
146	Purine bases	0.41(0.18-0.92)	(2-3)
147	Reducing substances	(7-20)	
148	Sugars, as glucose	1.4	
149	Taurine	(0.105-0.2)	
150	Volatile acids, total, ml of 0.1 N		2.66(1.61-4.45)

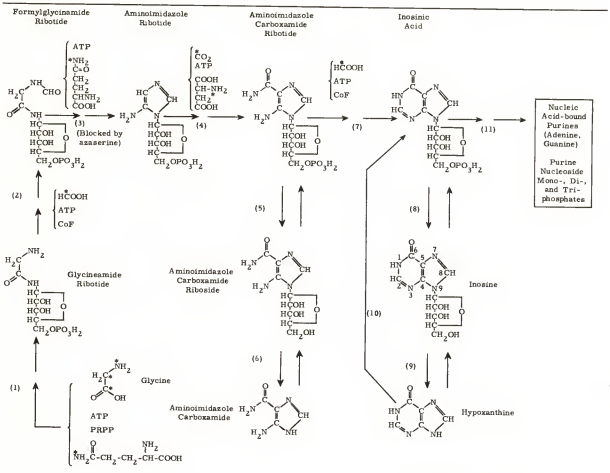
/1/ Present in nitrogen compounds, not as free nitrogen. /2/ Calculated from nitrogen of principal N-containing constituents, plus ammonia- and amino acid nitrogen. /3/ Identity not proven. /4/ Including regions in Texas where dental fluorosis is endemic. /5/ Age 10 mo. /6/ Age 8-12 yr. /7/ Not normally present in urine of adult males. /8/ Carotene and xanthophyll; 8-100 μg/kg body wt/da for xanthophyll alone.

Values are grams of nitrogen per 100 grams of total nitrogen excreted. Values in parentheses are ranges and conform to estimate "d" of the 95% range (cf Introduction).

	Species	Allantoin-N	Amino Acid-N	Ammonia-N	Creatine-N and Creatinine-N			Purine-N[1]	Urea-N	Uric Acid-N	Other Specified-N	Unidentified
					Creatine	Creatinine	Combined					
	Vertebrata											
	Mammalia											
1	Man (Homo sapiens)			4.8(3.2-5)		3.6	(3.1-4.9)		87(85-90)	0.65(0.5-1.5)		4(2-6.4)
2	Alpaca (Auchenia vicunna)			4.5	2.7	4.6			60	0.3		28
3	Bat (Xantharpyia spp)		0.96	6		8.5	8.5		63	0.87		20.3
4	Camel (Camelus dromedarius)		(0.2-1.7)	15(12-19)	3.8	14	(17.6-18.1)		44(33-56)	0.3		16.2(13-20)
5	Cat (Felis catus)			(3.9-8.1)		(0.57-1.9)			(72-84)	(0.2-0.22)		
6	Dog (Canis familiaris)			3.5(3.5-28)		0.8	(0.9-10)		91(46-92)			5(1.4-22)
7	Hyrax (Hyaena spp)	1.75	0.95	4.0	0.29	0.59	0.88	0.23	89	0.06		2.8
8	Leopard (Panthera pardus)	0.52	0.86	3.2	0.44	0.88	1.32	0.25	87	0.06		
9	Llama (Lama glama)	2.1.4	1.4(1.3-1.4)	2.0(1.8-2.2)	2.2	8.3	(9.1-11.7)		64(61-68)	0.8		
10	Seal (Phoca vitulina)			(2-7.5)			(9.1-31)		(61-90)	(6-11)		
11	Tiger (Panthera tigris)	1.3	0.95	3.3	0.43	1.29	1.72	0.18	89	0.06		3.4
12	Weasel (Mustela spp)	0.48	0.89		1.37	0.3	1.67	0.58	91	0.16		2.6
13	Whale (Balaenoptera physalus)			(1.9-3.6)		Trace	(0.3-3.8)		(85-93)	3(1.6-4.4)		(2.7-3.1)
	Aves											
14	Duck (Anas spp)			3.2					4.2	72		20.7
15	Fowl (Gallus domesticus)		6	1.5(1.5-17)		8	(7.4-9.1)	8	0.9(0.9-10)	70(63-87)		28
16	Goose (Anser spp)			13.5						80		6.5
17	Swan (Cygnus spp)			13.8					2.6	69		13.9
	Reptilia											
18	Alligator (Alligator spp)			(37-81)					(1.3-17)	(7-19.8)		(0.2-23)
19	Lizard (Chalcides ocellatus)	2.7								93		
20	Python (Python spp)		2.3	8.7						89		
21	Snake (Eryx thebaicus)		1.1	5.7			0.23	0.3		63	0.95[2]	29.1
22	Tortoise (Chelonia mydas)	(4.4-25)	(5.4-18.4)	(29-51)	2.6	0.9	(5.2-11.5)		(0-12)	(1.4-6.3)	8-23[2]	(2.4-22)
	Amphibia											
23	Frog (Rana catesbiana)			(3-38)					(62-88)	(Trace-0.4)		7.5
	Pisces											
24	Carp (Cyprinus spp)		2.6	(75-77)					(12.5-14.5)			(5.5-12.5)
25	Catfish (Ictalurus furcatus)		20	20			7.9		24.6			16.9
26	Cod (Gadus callarias)		(14.8-21.4)				(53-56)		(6.5-11.2)	(1.7-2.4)		(15.2-19)
27	Flounder (Pseudopleuronectes americanus)		8.9(8.2-9.7)	2.2(1.8-2.6)		20.5	(15-26)		17.3(13-21)	1.2(1.2-1.3)	0.4-1[3]	50(48-51)
28	Goosefish (Lophius piscatorius)		8.4(5.3-15)	0.6(0.3-1.3)		2.6	(24-64)		0.9(0.1-2.7)	0.2(0.2-0.4)	37[3]	(28-63)
29	Lungfish (Protopterus aethiopicus)			41	0.54	6.28			18.5	0.8		
30	Sheepshead (Archosargus probatocephalus)		(15-19.9)	(8.4-9.6)			(15.1-15.5)		(22.9-23)	(6.4-8.4)		(25-26)
	Invertebrata											
	Arthropoda											
31	Amphipod (Gammarus locusta)		(5-8)	(74-91)				(2-4)	(Trace-3)			(3-22)
32	Blowfly, larva (Calliphora spp)			Trace	Trace				Trace	Trace		14
33	Crab (Cancer pagurus)		20	43				10	12.9	2.8		11.5(4-11.5)
34	Crayfish (Astacus fluviatilis)		10(5-12)	60(53-65)				4.4(3.2-6.4)	11(10-12)	0.8(0.3-1.2)		14.7
35	Grasshopper (Melanoplus spp)		17.7	3.3					8.7	70		
36	Isopod (Oniscus asellus)		(0-12)	(44-50)				(14-38)		(4-5)		(8-25)
37	Moth (Tinea pellionella)		10	10.2					17.6	47.3		
	Mollusca											
38	Clam (Mya arenaria)		18	21.5				5	4.5	Trace		51
39	Mussel (Mytilus edulis)		24(17-36)	7.4(Trace-11.4)				9.7(Trace-16)	Trace			58(37-79)
40	Octopus (Octopus vulgaris)		20	50					15	1		14
41	Oyster (Gryphoea angulata)		13.2	7.2					3.2	1.6		75
42	Periwinkle (Littorina littorea)		7	12.6				29	40	0.8		11
43	Sea hare (Aplysia limacina)		13	34(30-37)				(15-167)	8.7(7.4-10)	4.6(Trace-9.2)		(24-45)
44	Slug (Arion empiricorum)		18(11.3-18)	9.8(7.1-9.8)				16.6(3-20)	2.8	3.3(1.4-10.3)		(52-80)
45	Snail (Helix pomatia)		7	22.2				19	16.8	7		35
46	Snail, pond (Limnaea stagnalis)		20	9.0				27.2		4.0		31.6
	Annelida											
47	Earthworm (Lumbricus terrestris)		(12.2-15)	(20.4-47)				17.5	(10.0-38.1)			10
48	Leech (Hirudo medicinalis)		4.5	78				4.3	3.8			9.1
49	Sea-mouse (Aphrodite aculeata)		35	13.3					11.1	1.1		39
	Echinodermata											
50	Sea-cucumber (Holothuria tubulosa)		18(18-18.7)	39(39-41)				12(12-12.5)	6(6-6.25)			25(18-25)

[1] Minus uric acid-N. [2] Hippuric acid-N. [3] Trimethylamine oxide-N.

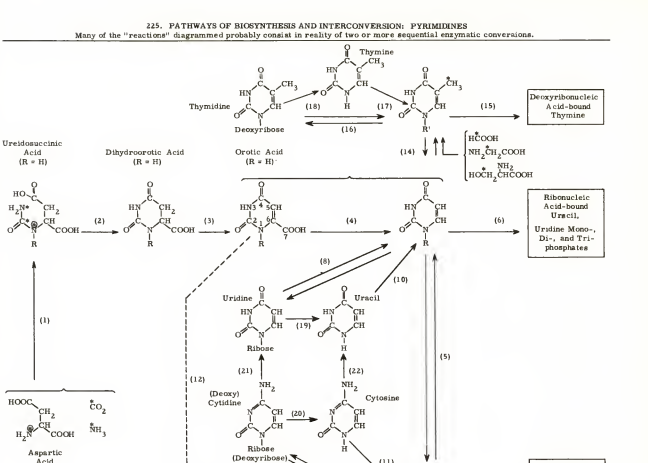
Many of the "reactions" diagrammed probably consist in reality of two or more sequential enzymatic conversions, the resolution of which awaits future developments.



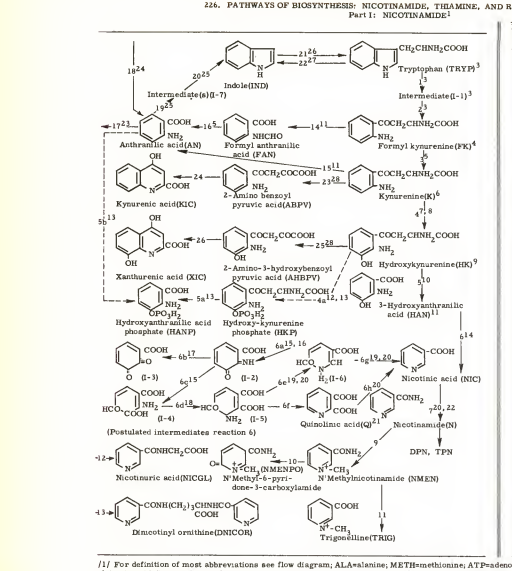
Abbreviations:
ATP Adenosine triphosphate
CoF Coenzyme form of folic acid
PRPP Phosphoribosylpyrophosphate
* Isotopically labeled atom incorporated into next product

/1/ Simple precursors utilizable in purine biosynthesis in several organisms include ammonium salts, glycine, which contributes purine carbons 4 and 5 and nitrogen 7, and glutamine, the amide nitrogen of which contributes purine nitrogen 9. ATP and PRPP (5'-phosphoribosylpyrophosphate) also are involved in the enzymatic synthesis of the intermediate glycinamide ribotide. /2/ Glycinamide ribotide is formylated in the presence of citrovorum factor or related derivatives to yield α-N-formylglycinamide ribotide. Labeled formate incorporated in this reaction ultimately contributes purine carbon 8. /3/ An aminoimidazolecarboxamide ribotide accumulates in cultures of a purineless Escherichia coli mutant. In the presence of ATP and glutamine, the amide nitrogen of which contributes purine nitrogen 3, formylglycinamide ribotide is converted enzymatically to aminoimidazole ribotide; the conversion is blocked by azaserine, which therefore enhances accumulation of formylglycinamide ribotide and its precursor. Formylglycinamidine ribotide is reported to be an intermediate in aminoimidazole ribotide formation in pigeon liver preparations. /4, 5, 6/ In de novo purine biosynthesis from simple precursors, labeled CO_2 contributes carbon 6. Aspartic acid (the nitrogen of which contributes the nitrogen 1 of purines), ATP, and CO_2 are required in the conversion of aminoimidazole ribotide to aminoimidazole carboxamide ribotide. Accumulation of aminoimidazolecarboxamide and its riboside and ribotide occurs in sulfa-inhibited E. coli cultures; accumulation of the carboxamide has been studied also in purineless E. coli mutant cultures. Aminoimidazolecarboxamide can be utilized as a purine precursor by several organisms. Enzymatic interconversions of the free base, riboside, and ribotide forms have been reported, including direct conversion of the free base to the ribotide in the presence of PRPP. /7/ The initial purine compound produced in de novo biosynthesis by pigeon liver preparations is inosinic acid. Formate, shown in early work to contribute purine carbon 2, reacts with aminoimidazolecarboxamide ribotide to form inosinic acid, in a conversion involving the citrovorum factor or other activated derivatives of reduced folic acid which may be formed enzymatically in the presence of ATP. Copper is an additional cofactor in the exchange of formate with inosinic acid. /8, 9, 10/ Inosine and hypoxanthine arise secondarily via breakdown of inosinic acid; enzymatic interconversions of these metabolites occur, as well as direct conversion of hypoxanthine to inosinic acid in the presence of ribose-5-phosphate. /11/ The conversion of inosinic acid to other purine compounds (adenine, guanine) may involve as intermediates derivatives such as adenylosuccinic acid. Little is known of the mechanisms of polymerization of nucleotides into nucleic acids; however, a recent report indicates there may be involved the formation of long-chain polynucleotides by linking nucleoside diphosphates together by means of a phosphorylase type of reaction with the liberation of inorganic phosphate. Mono-, di-, and triphosphates of the purines as well as of the pyrimidines have been found to occur free in tissues, and considered as possible precursors in nucleic acid polymerization.

Many of the "reactions" diagrammed probably consist in reality of two or more sequential enzymatic conversions.



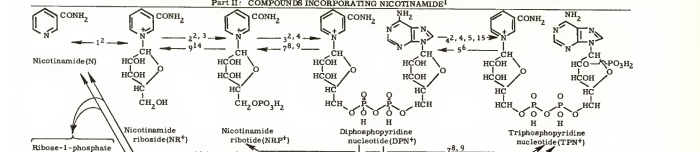
/1/ Aspartic acid contributes preferentially nitrogen 1, ⑨ and less effectively N-3, (ammonium-N contributes preferentially N-3) as well as carbons 4, 5, 6, and 7 to orotic acid in rat liver slices; it contributes the imido-N of ureidosuccinic acid in rat liver mitochondria, and has been shown to be involved in pyrimidine biosynthesis in lactobacilli. Labeled ammonium-N enters nucleic acid cytosine and thymine of pigeons, and enters combined pyrimidines in rats; it is an effective precursor of orotic acid N-1 and N-3 (equally) in rat liver, and of uracil N-1 in rat liver. Labeled ammonium-N contributes the carbamino-N of ureidosuccinic acid in rat liver mitochondria, is a reaction dependent upon ATP, aspartate, and carbamylglutamate. The carbamylation of aspartic acid may be closely analogous to that of ornithine. Labeled bicarbonate, or carboxyl of acetate, enters position 2 of uracil in rats, and of orotic acid in rat liver slices. Labeled CO_2 is fixed into nucleic acid pyrimidines of certain microorganisms. Labeled formate-C does not extensively enter nucleic acid uracil in rats, nor in yeast; the carbons of glycine are not extensively incorporated into the pyrimidine bases of rats. /2,3/ Ureidosuccinic acid replaces orotic acid for Lactobacillus bulgaricus 09, which utilizes no other simple pyrimidine derivatives except as more recently reported, uridine-5'-phosphate and dihydroorotic acid. Ureidosuccinic acid is utilized for orotic acid synthesis in rat liver; it is converted to orotic acid through dihydroorotic acid by certain bacteria. The suggestion has been made that conjugation, such as ribosidation, of an acyclic pyrimidine precursor precedes ring closure and decarboxylation; more recently the free compounds (R=H in diagram) have been suggested as the true intermediates in orotic acid biogenesis. /4/ Orotic acid is utilized by a pyrimidineless Neurospora mutant and by L. bulgaricus 09 (see above). Orotic acid labeled with N^{15} or C^{14} enters the uridine and cytidine components of liver polynucleotides in rats. Orotic acid-$6C^{14}$ enters uracil of yeast. /5,6,7/ Presumably a conjugated form of uracil is aminated to form a cytosine derivative; such interconversion may take place in the polynucleotide stage. The stage at which pentose is replaced by deoxyribose is not definitely known; labeled C-2 of uracil deoxyriboside incubated with tissue suspensions was incorporated only into DNA thymidine, and no other DNA or RNA component. Little is known of the mechanisms of polymerization of nucleotides into nucleic acids. Mono-, di-, and triphosphates of the pyrimidine ribonucleosides have been found to occur free in tissues, and considered as possible precursors in nucleic acid polymerization; uridine-5'-phosphate is formed from orotic acid by pigeon liver in the presence of 5-phosphoribosylpyrophosphate. /8,9/ N^{15}-Labeled cytidine, and uridine (with much more isotope dilution), are incorporated by rats into nucleic acids; deoxycytidine is utilized for thymine and cytosine synthesis. /10,11/ Certain pyrimidineless Neurospora mutants utilize uridine or cytidine, or the corresponding free pyrimidines much less effectively. Cytidine and uridine may not be intermediates in uracil utilization in a Neurospora strain. Many organisms utilize uracil, cytosine, and their conjugated derivatives interchangeably as growth factors; however, for other microorganisms a specific pyrimidine requirement, e.g. for uracil or uridine, cannot be replaced by other pyrimidines. Although orotic acid (see above) is utilized by rats in nucleic acid formation, neither uracil nor cytosine is so utilized. /12,13/ It has been suggested that orotic acid after amination may be converted to cytidine and the latter deaminated to uridine. /14,15/ The stage of pyrimidine synthesis at which the methyl group is introduced to form thymine derivatives is not definitely known. 5-Nitrouracil competitively inhibits uracil utilization for the formation of a product replaceable by thymine. Uracil is converted to thymine by certain microorganisms. Labeled formate-C, alpha-C of glycine, or beta-C of serine provides the 5-methyl-C of deoxyribonucleic acid thymine in rats. /16,17/ Some organisms, e.g. Leuconostoc mesenteroides, utilize thymine and uracil interchangeably. Thymine is not utilized by rats in nucleic acid formation. Thymidine but not thymine in certain organisms prevents the toxicity of folic acid antagonists of sulfonamides; thymidine is utilized for synthesis of DNA-thymine in rats. In other organisms thymidine and thymine function interchangeably. Lactobacillus bifidus utilizes thymidine, thymidylic acid or certain other pyrimidine derivatives for growth. /18,19,20/ Nucleosidases for the pyrimidines have been reported. /21,22/ Enzyme preparations and other biological systems have been reported which deaminate cytosine. An Escherichia coli enzyme preparation specifically deaminates cytidine or cytosine deoxyriboside.



Reaction No.	Reactants	Products	Enzyme
1	TRYP+H_2O_2	I-1+?	TRYP-peroxidase oxidase
2	I-1+O_2	FK	TRYP-peroxidase oxidase
3	FK+H_2O	K+HCOOH	K-formamidase
4	K+?	HK+?	?
5	HK+H_2O	HAN+ALA	Kynureninase
4a	K+?	HKP+?	?
5a	HKP+?	HANP+?	?
5b	AN+?	HANP+?	?
6	HAN+$\frac{1}{2}$ O_2	NIC+H_2O+ CO_2	Many?
6a	HAN+$\frac{1}{2}$ O_2	I-2+H_2O	HAN-oxidase
6b	I-2+H_2O	I-3+NH_3	Spontaneous
6c	I-2+2(H)+ 2(O)	I-4	?
6d	I-4	I-5	?
6e	I-5	I-6+CO_2	?
6f	I-6	Q+H_2O	Spontaneous
6g	I-6	NIC+H_2O	?
6h	Q	NIC+CO_2	?
7	NIC+?	N+?	?
8	N	DPN*, TPN*	Many
9a	METH+ATP	SADMETH+ ^{3}PP$_i$	METH-activating enzyme
9b	N+ SADMETH	NMEN+SA -HCYS	N-methylphersase
10	NMEN+O_2	NMENPO+ $\frac{1}{2}H_2O_2$	Quinine oxidase
11	NMEN+H_2O	TRIG+NH_3	?
12		NICGL	?
13		DNICOR	?
14	FK+H_2O	FAN+ALA	Kynureninase
15	K+H_2O	AN+AL A	Kynureninase
16	FAN+H_2O	AN+ HCOOH	K-formamidase
17	AN+O_2	Various products	Many
18	Precursors	AN	Many
19	AN+?	I-7+CO_2 +?	
20	I-7+?	IND+?	?
21	IND+SER	TRYP+ H_2O	IND-SER ligase
22	TRYP+H_2O	IND+PVA+ NH_3	Tryptophanase
23	K+AKG	ABPV+ GLU	K-transaminase
24	ABPV	XIC+H_2O	Spontaneous
25	HK+AKG	AHBPV+ GLU	K-transaminase
26	AHBPV	XIC+H_2O	Spontaneous

/1/ For definition of most abbreviations see flow diagram; ALA=alanine; METH=methionine; ATP=adenosine triphosphate; AKG=ketoglutaric acid; GLU=glutamic acid; SER=serine; PVA=pyruvic acid; DPN=diphosphopyridine nucleotide; TPN=triphosphopyridine nucleotide. /2/ Dietary TRYP substitutes for N and causes increased formation of NMEN, NIC, Q, and pyridine nucleotides. Tracer experiments have shown that: TRYP-9-C^{14}→K-8-C^{14} + KIC-3-C^{14}, TRYP-3-C^{14}→NMEN-7-C; TRYP-1-N^{15}→K-N^{15} + KIC-N^{15} + XIC-N^{15} + NMENPO-N^{15}; K-N^{15}→XIC-N^{15}, TRYP-5, 6, 7, 8-D_4-1-N^{15}→Q-D_2-1-N^{15}; IND-1-N^{15}→NIC-1-N^{15}, AN-N^{15}, IND-N^{15}, or TRYP-1-N^{15}→TRYP-1-N^{15} + Q-1-N^{15}. /3/ Reactions 1 and 2 have not been separated and intermediate not identified. The activity (amount?) of these enzymes is dependent upon the dietary intake of TRYP and is subject to hormonal control. /4/ Suggested compound identified as product of reaction 2. /5/ This enzyme catalyzes reactions 3 and 16 and also acts on other N-formyl compounds. /6/ As N-Acetyl-K, is accumulated by niacinless mutant of Neurospora. Dietary K can substitute for N and causes increased excretion of NMEN. /7/ This reaction postulated because of activity of K (Fn 6), HAN (Fn 10), and, subsequently, HK (Fn 9). It has not been shown in cell-free system. /8/ B_2 involved as catalyst in oxidation or oxidative phosphorylation of K. /9/ HK postulated as precursor of HAN. It is a naturally occurring substance and can serve as substitute for NIC in Neurospora. /10/ This enzyme catalyzes reactions 5, 14, and 15. It requires pyridoxal phosphate as coenzyme. It is inhibited by amines. /11/ A compound accumulated by niacinless mutant of Neurospora, identified as HAN, can substitute for NIC in diet. It is converted to NIC, causes increased excretion of NMEN, and is oxidized to Q by liver preparations. /12/ Reaction and reaction product postulated (see also Fn 13). /13/ Reactions 4a, 4b, and 5b postulated on basis of report that TRYP, K, and AN are oxidized by liver homogenate to product tentatively identified as HANP, whereas HK is split to HAN. However, most authors find that AN is not a source of NIC in mammals. /14/ Reaction well established (see Fn 10) but details still obscure (see reactions 4a-4b). /15/ Reaction 6a or 6c requires O_2 and Fe^{++}. It is inhibited by a, a-dipyridyl, p-chloromercuribenzoate, H_2O_2, and HCN. /16/ Intermediate tentatively identified on basis of absorption spectrum, chemical properties, and conversion to I-3. /17/ This reaction, catalyzed by H^+, gives a product, tentatively identified as I-3, that cannot be converted to Q. /18/ I-4 and I-5 tentatively identified by absorption spectra and chemical properties. /19/ Reaction postulated because of low activity of Q (see Fn 21). /20/ Reaction has not been shown in cell-free system. /21/ Acid-labile substance accumulated in urine identified as Q and is accumulated by niacinless mutant strain of Neurospora and mammals. To a limited extent, Q is utilized by Neurospora and mammals. May or may not be an intermediate. /22/ Although all mammals appear to utilize either NIC or N interchangeably, the reaction has not been demonstrated in cell-free system. NIC is not necessarily an intermediate. /23/ In some bacteria, AN is oxidized by way of catechol, and cis-muconic acid to β-keto adipic acid. /24/ The ultimate origin of AN from carbohydrate is closely linked with the origin of other aromatic compounds. /25/ The carboxyl group of AN is lost during these reactions. /26/ Enzyme requires pyridoxal phosphate as coenzyme. /27/ Reaction requires pyridoxal phosphate as coenzyme. /28/ Enzyme requires pyridoxal phosphate as coenzyme. Either α-ketoglutaric or pyruvic acid can accept the amino group. With model compounds which cannot undergo ring closure the reaction is reversible. K can be oxidatively deaminated slowly by L-amino acid oxidase to form ABPV which spontaneously dehydrates to KIC. The relative rates of reactions 4, 5, 23, 25 depend upon the dietary intake of B_1, B_2, and B_6.

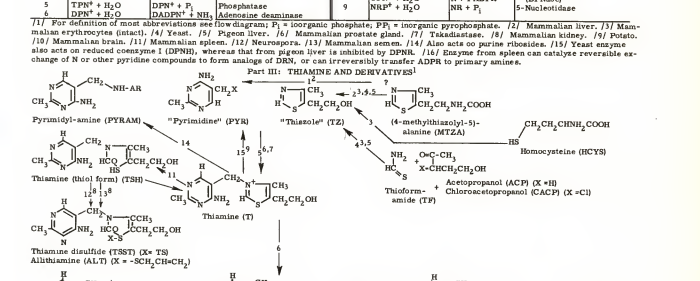
Part II: COMPOUNDS INCORPORATING NICOTINAMIDE[1]



Reaction No.	Reactants	Products	Enzyme	Reaction No.	Reactants	Products	Enzyme
1	N + R1P	NR^+ + Pi + H^+	Unnamed phosphorylase	7	$DPN^+ + H_2O$	NRP^+ + AMP	Nucleotide pyro-phosphatase
2	NR^+ + ATP	NRP^+ + ADP	Unnamed kinase		$TPN^+ + H_2O$	NRP^+ + PAMP	
3	NRP^+ + ATP	$DPN^+ + PP_i$	DPN-pyrophosphorylase	8	$DPN^+ + H_2O$	N + ADPR	DPN nucleosidase
4	DPN^+ + ATP	TPN^+ + ADP	DPN-kinase		$TPN^+ + H_2O$	N + PADPR	(DPNase)
5	$TPN^+ + H_2O$	$DPN^+ + P_i$	Phosphatase	9	$NRP^+ + H_2O$	NR + P_i	5-Nucleotidase
6	$DPN^+ + H_2O$	$DADPN^+ + NH_3$	Adenosine deaminase				

/1/ For definition of most abbreviations see flow diagram; P_i = inorganic phosphate; PP_i = inorganic pyrophosphate. /2/ Mammalian liver. /3/ Mammalian erythrocytes (intact). /4/ Yeast. /5/ Pigeon liver. /6/ Mammalian prostate gland. /7/ Takadiastase. /8/ Mammalian kidney. /9/ Potato. /10/ Mammalian brain. /11/ Mammalian spleen. /12/ Neurospora. /13/ Mammalian semen. /14/ Also acts on purine ribosides. /15/ Yeast enzyme also acts on reduced coenzyme I (DPNH), whereas that from pigeon liver is inhibited by DPNH. /16/ Enzyme from spleen can catalyze reversible exchange of N or other pyridine compounds to form analogs of DRN, or can irreversibly transfer ADPR to primary amines.

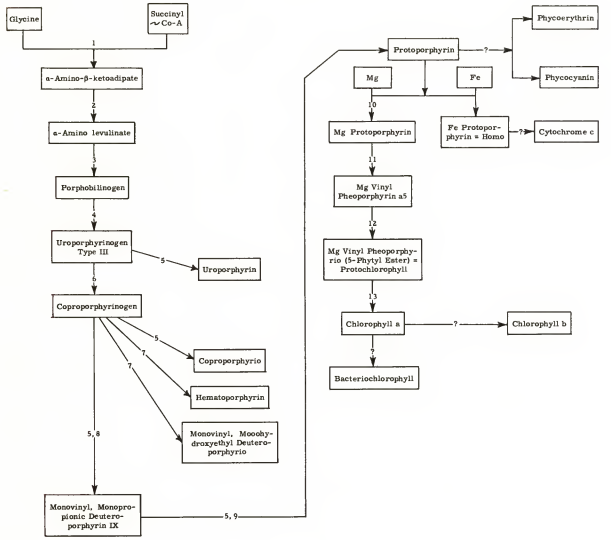
Part III: THIAMINE AND DERIVATIVES[1]



Reaction No.	Substrates	Products	Enzyme	Reaction No.	Substrates	Products	Enzyme
1	? + ?	PYR + ?	?	9	$TDP + H_2O$	$TMP + P_i$	Nucleotide pyrophosphatase
2	MTZA + ?	TZ + NH_3 + CO_2	?	10	TDP + LA + ATP+CoA	LTDP + ?	Lipoic acid conjugase
3	HCYS + ?	TZ + ?	?				
4	TF + ACP	TZ + ?	?	11	T + OH	TSH + H_2O	Spontaneous?
	TF + CACP	TZ + ?	?	12	TSH + TSH	TSST + 2H	Thiamine disulfylase
5	PYR + TZ	T	Unnamed	13	AL + ?	ALC + ?	Allinase
6	T + ARP	TDP + AMP	Thiamine pyrophosphorylase		TSH + ALC	ALT + ?	Spontaneous
7	TTP + H_2O	TDP + P_i	Potato apyrase	14	T + AR-NH_2	PYRAM + TZ	Thiamine I
8	TDP + H_2O	TMP + P_i	Potato apyrase	15	$T + H_2O$	PYR + TZ	Thiaminase II

/1/ For definition of abbreviations see flow diagram; ATP=adenosine triphosphate; AMP=adenosine monophosphate; P_i=inorganic phosphate; AL=allin; CH_2=CHCH$_2$SOCH$_2$CHNH$_2$COOH; ALC=allicin, CH_2=CHCH$_2$SSOCH$_2$CH$_2$=CH$_2$; AR-NH=any of a variety of aromatic amines; LA=lipoic acid; CoA=coenzyme A. /2/ Constitution and origin of PYR not established; presumably, X=OH or NH_2. /3/ Growing pea roots. /4/ Intact yeast cells. /5/ Natural occurrence of MTZA, TF, ACP, CACP not established. /6/ There is evidence that this may not be sole or predominant pathway. /7/ The name "thiaminase" was first used for this enzyme, but is now reserved for the enzyme(s) which catalyze reactions 14 and 15. /8/ TSST and ALT are nutritionally equivalent to T. /9/ In the product (PYR), X=OH.

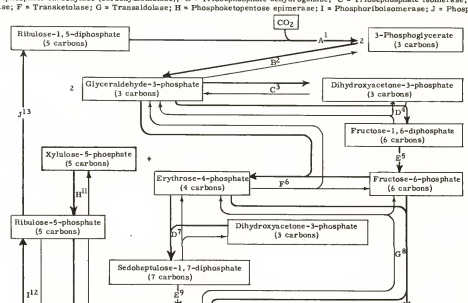
The diagram summarizes present knowledge and hypothesis of the pathway leading to the synthesis of chlorophyll in plants.



/1/ Condensation of glycine with "succinyl ~Co-A" produces δ-amino-β-ketoadipate. /2/ Decarboxylates to δ-amino levulinate. /3/ Two molecules of δ-amino levulinate condensed by a dehydrase enzyme, forming the pyrrole amine, porphobilinogen. /4/ Four molecules of porphobilinogen coodensed, forming a reduced porphyrin, uroporphyrinogen, isomer III /5/ It is uncertain how far along the biosynthetic chain tetrapyrnole remains in the reduced form. /6/ Decarboxylation of uroporphyrinogen III to coproporphyrinogen III. /7/ It is uncertain whether these compounds are intermediates or side products. Found in chlorella mutant. /8/ Oxidatioo of ooe propionic side chain to vinyl. /9/ Oxidation of one propionic side chain to vinyl, producing protoporphyrin. Found in a chlorella mutant devoid of chlorophyll and carotenoids. /10/ Mg protoporphyrin found in chlorella mutant. /11/ Four or five steps postulated, including reduction of vinyl side chain to ethyl, oxidation of propionic group and cyclizatioo to a cyclopentanone ring, and esterification with methanol. Found in a chlorella mutant. /12/ Esterification of a propionic acid group with phytol, a C-20 alcohol. /13/ Open chain bile pigment chemically bound to protein.

228. PATHWAYS OF PHOTOSYNTHESIS: CARBON DIOXIDE REDUCTION CYCLE

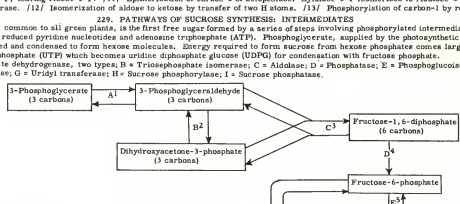
Photosynthetic carbon dioxide-reduction follows the same general pathway in all plants. The first reaction results in formation of two molecules of phosphoglycerate from carbon dioxide and ribulose diphosphate. Phosphoglycerate is then reduce via the reverse of glycolysis reactions to give hexose-phosphates for synthesis of sucrose and polysaccharides. A portion of the intermediates undergoes the following sequence of reactions leading to regeneration of the carbon dioxide acceptor, ribulose diphosphate. Heavy arrows indicate directions of material transfer during steady state photosynthesis.
A = Ribulose diphosphate carboxylase (carboxydismutase); B = Triosephosphate dehydrogenase; C = Triosephosphate isomerase; D = Aldolase, E = Phosphatase; F = Transketolase; G = Transaldolase; H = Phosphoketopentose epimerase; I = Phosphoribulosomerase; J = Phosphoribulokinase.



/1/ Ribulose diphosphate adds CO_2 at carbon-2 and splits hydrolytically to give two molecules of 3-phosphoglycerate. /2/ The carboxyl group is reduced to an aldehyde group with the aid of ATP and reduced TPN. /3/ Isomerization involves transfer of 2H from carbon-2 to carbon-1. /4/ Aldol condensation of carbon-1 of glyceraldehyde-3-P with carbon-1 of dihydroxyacetone-3-P. /5/ Removal of phosphate ester group from carbon-1 by hydrolysis. /6/ Glycolyl group (carbon-1,2) of fructose transferred to glyceraldehyde-P to form xylulose-5-P, leaving erythrose-P. /7/ Aldol condensation of carbon-1 of erythrose-4-P with carbon-1 of dihydroxyacetone-3-P obtained from step 3. /8/ Transfer of triose group (carbon-1,2,3) from fructose-6-P to carbon-1 of erythrose-4-P, leaving glyceraldehyde-3-P from carbon-4,5,6 of the fructose-6-P. /9/ Hydrolysis of phosphate ester group on carbon-1 to give inorganic phosphate. /10/ Transfer of glycolyl group (carbon-1,2) of sedoheptulose-7-P to carbon-1 of glyceraldehyde-3-P to give ribulose-5-P, leaving ribose-5-P. /11/ Epimerization of carbon-3 of ketopentose. Xylulose-5-P isomerizes to ribulose-5-P with phosphoketopentose epimirase. /12/ Isomerization of aldose to ketose by transfer of two H atoms. /13/ Phosphorylation of carbon-1 by reaction with ATP.

229. PATHWAYS OF SUCROSE SYNTHESIS: INTERMEDIATES

Sucrose synthesis, common to all green plants, is the first free sugar formed by a series of steps involving phosphorylated intermediates. Photosynthesis supplies reduced pyridine nucleotides and adenosine triphosphate (ATP). Phosphoglycerate, supplied by the photosynthetic carboxylation reaction, is reduced and condensed to form hexose molecules. Energy required to form sucrose from hexose phosphates comes largely from high energy uridine triphosphate (UTP) which becomes uridine diphosphate glucose (UDPG) for condensation with fructose phosphate.
A = Triosephosphate dehydrogenase, two types; B = Triosephosphate isomerase; C = Aldolase; D = Phosphatase; E = Phosphoglucoisomerase; F = Phosphoglucomutase; G = Uridyl transferase; H = Sucrose phosphorylase; I = Sucrose phosphatase.



/1/ DPNH or TPNH are oxidized to supply hydrogen for reduction of carboxyl to aldehyde group. ATP and Mg^{++} are required for this reaction.
/2/ Two hydrogen atoms shift from carbon-2 to carbon-1 to form isomeric phosphoketose from 3-phosphoaldotriose. /3/ Aldol condensation of carbon-1 of phosphoketotriose and carbon-1 of 3-phosphoaldotriose. /4/ Phosphate group on carbon-1 hydrolysed. /5/ Hydrogen atom on carbon-1 shifts to carbon-2 forming the epimer, glucose-6-phosphate. Furanose ring structure changed to pyranose. /6/ Phosphate group on carbon-6 transferred to carbon-1 through the required coenzyme intermediate, glucose-1, 6-diphosphate. Mg^{++} required. /7/ UTP reacts with glucose-1-phosphate to form pyrophosphate and UDPG. /8/ Fructose-6-phosphate and UDPG react to give UDP and an unstable sucrose phosphate. /9/ Hydrolysis to give free sucrose and orthophosphate.

230. PHOTOSYNTHESIS: RATES

Photosynthesis under natural conditions is complicated by such factors as light intensity, temperature, CO_2 concentration, and by certain internal conditions of the plant. For a comparison of the rates of photosynthesis, Part I presents maximum rates for natural conditions; Part II, maximum rates for controlled, near-optimum conditions. Part III gives rates as influenced by controlled conditions of temperature, light, and CO_2. Values are apparent rates, i.e., uncorrected for respiration.

Part I: APPARENT MAXIMUM RATES OF PHOTOSYNTHESIS: NATURAL CONDITIONS

Values are mg CO_2/100 sq cm per hr.

	Species	CO_2 Fixation[1]
	Arctic Zone	
1	Dock (Rumex acetosella); 10°C	12
2	Chamaenerium (Chamaenerium latifolium); 0°C	10
3	Cloudberry (Rubus chamaemorus)	8
4	Willow (Salix glauca); 10°C	4
5	Willow (S. glauca); 20°C	6
	Temperate Zone	
6	Anemone (Anemone nemorosa)	(6–11)
7	Apple (Pyrus malus)	20(20)
8	Corn (Zea mays)	10
9	Dock (Rumex acetosella)	9
10	Elder (Sambucus nigra)	4, 6(1, 7)
11	Fern, polypody (Polypodium virginiana)	(5, 6)
12	Horse-bean (Vicia faba)	17
13	Mustard (Sinapis alba)	20–26
14	Oat (Avena sativa)	13
15	Pine (Pinus taeda)	14, 3(2, 5)
16	Potato (Solanum tuberosum)	20
17	Rhododendron (Rhododendron brachycarpum)	(2, 8)
18	Sunflower (Helianthus annuus)	5, 5–24
19	Tomato (Lycopersicon esculentum)	16, 8

	Species	CO_2 Fixation[1]
	Desert Zone	
20	Atriplex (Atriplex vesicarium)	10
21	Date (Phoenix dactylifera)	3, 4
22	Grape (Vitis vinifera)	16, 1
23	Heliotrope (Heliotropium argurioides)	27
24	Limoniastrum (Limoniastrum feei)	1, 3
25	Oleander (Nerium oleander)	10, 3
	Tropical Zone	
26	Calophyllum (Calophyllum inophyllum)	7, 3
27	Cassia (Cassia fistula)	10, 9(8, 6)
28	Coconut (Cocos nucifera)	0, 9
29	Mango (Mangifera indica)	14, 8
30	Sugarcane (Saccharum officinarum)	5
	Mountain Zone	
31	Barley (Hordeum sativum)	≧ 30
32	Eurotia (Eurotia ceratoides)	≧ 44
33	Gentiana (Gentiana algicola)	≧100
34	Geum (Geum montanum)	48
35	Homogyne (Homogyne alpina)	43(18)
36	Soldanella (Soldanella alpina)	39(19)
37	Veronica (Veronica bellidioides)	65

/1/ Values from determinations made in shade are enclosed in parentheses; all others, in sunlight.

Part II: APPARENT MAXIMUM RATES OF PHOTOSYNTHESIS: NEAR-OPTIMUM CONDITIONS

	Species	CO_2 in Air %	Temperature °C	CO_2 Fixation, g CO_2/hr				Assimilation Time (T_A)[2], sec
				per 100 g wet wt	per 100 g dry wt	per sq dm x 1000	per g chlorophyll (*ν*/*A*)[1]	
1	Basswood (Tilia cordata)	5	25	1, 88	5, 8	28	6, 6	24
	Elder (Sambucus nigra)							
2	Green leaves	5	25	1, 96	5, 3	34	6, 6	24
3	Yellow leaves	5	25	0, 88	4, 7	18	120	1, 3
	Maple (Acer pseudoplatanus)							
4	Young leaves	5	25	0, 98	3, 0	16	11, 8	13
5	Old leaves	5	25	2, 07	5, 8	26	5, 2	30
6	Poplar (Populus pyramidalis)	5	25	1, 90	6, 0	40	10, 0	16
7	Sunflower (Helianthus annuus)	5	25	2, 30	13, 4	80	14, 0	11
	Chlorella (Chlorella pyrenoidosa)							
8	In shade, ← carbonate buffer 9				11, 5		4, 1	36
9	In light, ← carbonate buffer 9				13, 4		2, 8	56
10	Sea lettuce (Ulva lactuca)		25			11, 8		
11	Sea weed (Gigartina harveyana)[3]		16			14		
12	Water net (Hormidium flaccidum)		20				6, 8	23

/1/ ν/A, the assimilation number, i.e., the maximum quantity of CO_2 that can be reduced in unit time by unit quantity of chlorophyll. /2/ The shortest time in which one molecule of chlorophyll can reduce one molecule of CO_2. /3/ In artificial sea water containing 0.016 M bicarbonate/carbonate buffer.

Part III: APPARENT RATES OF PHOTOSYNTHESIS: SPECIFIED CONDITIONS

	Species	Temperature[1] °C	Light[1] ft-c	CO_2 in Air[1]	Photosynthesis Rate[2]	Unit of Expression per hr
1	Barley (Hordeum vulgare)	24	500	N	9–16	mg CO_2/sq dm
2	Bean (Phaseolus vulgaris)	25	1400	N	5, 8–16, 6	mg CO_2/sq dm
3	Dogwood (Cornus florida)	30	2000	N	2(3, 1)	mg CO_2/sq dm
4	Laurel (Prunus laurocerasus)	29, 5	Noon sun	N	23, 2	mg CO_2/sq dm
5	Lemon (Citrus limonia)		1300	1, 5%	3–5	ml O_2/sq dm
6	Oak (Quercus rubra)	30	2000	N	5(6)	mg CO_2/sq dm
7	Orange (Citrus sinensis)		1300	1, 5%	4–6	ml O_2/sq dm
8	Pelargonium (Pelargonium zonale)	24	500	N	5, 3	mg CO_2/sq dm
9	Pine (Pinus taeda)	30	2000	N	2(3, 9)	mg CO_2/sq dm
10	Potato (Solanum tuberosum)	24	>5000	N	16–20	mg CO_2/sq dm
11	Spruce (Picea pungens)	24	2200	N	0, 03	mg CO_2/100 leaves
12	Sugar cane (Saccharum officinarum)	36	N	N	3–6	mg CO_2/sq dm
13	Sunflower (Helianthus annuus)		4460	5%	(80)	mg CO_2/sq dm
14	Sphagnum (Sphagnum girgensohnii)		210–260		2, 8	mg CO_2/g dry wt
15	Chlorella (Chlorella vulgaris viridis)	22, 4	26, 700 lux	Buffer 9[3]	195	cu mm O_2/100 mil cells
16	Chlorella (C. saccharophila)	22, 4	26, 700 lux	Buffer 9[3]	452	cu mm O_2/100 mil cells
17	Kelp (Macrocystis pyrifera)	N	Low	Sea water	17, 5	ml O_2/sq dm

/1/ N=under natural conditions. /2/ Values in parentheses are maximum rates; all others, average rates. /3/ Carbonate buffer 9.

231. PHOTOSYNTHESIS: EFFICIENCY AND CARBON PRODUCTION

Part I: ESTIMATED ANNUAL CARBON PRODUCTION

	Region	Area	Carbon Fixed, ton/yr	
		sq km	per sq km	total
1	Forest	44×10^6	250	11×10^9
2	Cultivated land	27×10^6	149	$4, 3 \times 10^9$
3	Grassland	31×10^6	43	$1, 1 \times 10^9$
4	Desert	47×10^6	7	$0, 2 \times 10^9$
5	Total land	149×10^6		$16, 6 \times 10^9$
6	Ocean	361×10^6	340	$16, 6 \times 10^9$

Part II: EFFICIENCY OF PHOTOSYNTHESIS

	Specification	Value
1	Energy utilized in photosynthesis by one acre of corn plants in synthesis of 8732 kg glucose[1].	$3, 3 \times 10^7$ Cal
2	Total solar energy available on the acre during growing season.	$2, 043 \times 10^9$ Cal
3	Photosynthetic efficiency of corn plants, i.e., per cent of available energy used in photosynthesis.	1, 6%
4	Energy equivalent of earth's carbon production.	$(13, 6 \pm 8, 1) \times 10^{17}$ Cal
5	Mean solar radiation.	$7, 4 \times 10^{14}$ Cal
6	Photosynthetic efficiency of the world.	0, 18(±0, 12%)

/1/ Total sugar, as glucose, manufactured by one acre of corn plants.

232. PHOTOCHEMICAL ACTIVITIES: PLANTS

Data are concerned with the following: photosynthesis (light dependent reduction of CO_2 with evolution of equimolar O_2), hill reaction (light dependent reduction of a hydrogen acceptor other than CO_2 with evolution of equivalent O_2), photoreduction (light dependent reduction of CO_2 with oxidation of equivalent exogenous hydrogen donor), photofermentation (light dependent evolution of H_2 and CO_2 from endogenous reserves of exogenous substrate), and photochemical phosphorylation (light dependent esterification of inorganic phosphate). Except where otherwise indicated, light intensity is incident.

Part I: REDUCTION OF CO_2 WITH EVOLUTION OF O_2: INTACT CELLS

	Species	Sample: Units	Sample: Total Sample	Temp °C	Radiant Energy: Type	Radiant Energy: Intensity ergs/sq cm x sec	Rate of Reaction
1	Chlorella ellipsoidea	0.192 mg dry wt/ml	20 ml	25	Tungsten lamp	1.15×10^3	1.9×10^{-4} µM O_2/mg/sec
2						2.41×10^3	3.9×10^{-4} µM O_2/mg/sec
3						5.30×10^3	7.6×10^{-4} µM O_2/mg/sec
4						1.04×10^4	1.2×10^{-3} µM O_2/mg/sec
5						2.41×10^4	1.5×10^{-3} µM O_2/mg/sec
6						1.84×10^4	1.5×10^{-3} µM O_2/mg/sec
7						Saturation	1.6×10^{-3} µM O_2/mg/sec
8	C. pyrenoidosa	$1.5\text{-}2.0 \times 10^7$ cells/ml	1.0 ml	28	6500 Å	616 ergs/sec absorbed	8.2×10^{-4} µl O_2/sec
9		1.2 µl cells/ml	8.2 ml	26	Tungsten lamp	1.51×10^4	9.9 µl O_2/10 min
10	C. vulgaris	1.15×10^7 cells/ml	2.4×10^8 cells	23-25	Tungsten lamp	8.37×10^2	0.8 µl O_2/min
11						2.39×10^3	1.8 µl O_2/min
12						5.98×10^3	$3.7\text{-}3.8$ µl O_2/min
13						3.29×10^4	$4.7\text{-}6.1$ µl O_2/min
14	C. vulgaris viridis	10 µl cells/ml	2.0 ml	29.8	Na-vapor lamp	1.45×10^4	175 µl CO_2/hr
15	Chlorobium thiosulfatophilum	2.5 mg wet wt/ml	3.0 ml		Tungsten lamp	0.2	25 µl CO_2/hr
16						0.4	60 µl CO_2/hr
17						0.6	80 µl CO_2/hr
18	Alfalfa (Medicago sativa)	Whole plant	560 g	15.6	Sunlight	2.02×10^5	18 g CO_2/80 min
19			560 g	15.6		3.37×10^5	28 g CO_2/80 min
20			665 g	25.7		5.73×10^5	39 g CO_2/80 min
21	Corn (Zea mays)	Whole plant	Entire leaf	18-34	Sunlight	3.02×10^4	$0.4\text{-}2.3$ g CO_2/sq m/hr
22				18-34		1.21×10^5	1.7 g CO_2/sq m/hr
23				18-34		1.51×10^5	$0.9\text{-}3.5$ g CO_2/sq m/hr

Part II: REACTIONS OTHER THAN AN EXCHANGE OF CO_2 AND O_2: INTACT CELLS

	Species	Sample: Units	Sample: Total Sample	Temp °C	Radiant Energy: Type	Radiant Energy: Intensity erg/sq cm/sec	H_2 Acceptor or [Donor]	Rate of Reaction
	Photochemical Reduction, with H_2O as H_2 Donor							
1	Chlorella pyrenoidosa	16 µl cells/ml	2.0 ml	10	Fluorescent lamp	Saturation	p-Quinone	85 µl O_2/30 min
2		50 µl cells/ml	2.0 ml	20	Tungsten lamp	Saturation	p-Quinone	165 µl O_2/15 min
3		96 mg dry wt/ml	1.0 ml	28	Tungsten lamp	1.36×10^4	Benzaldehyde	50 µl O_2/20 min
4		96 mg dry wt/ml	1.0 ml	28	Tungsten lamp	1.36×10^4	Acetaldehyde	40 µl O_2/20 min
	Photochemical H_2 Evolution: Photofermentation							
5	Chlamydomonas moewusii	24 µl cells/ml	4.0 ml	25	Fluorescent lamp	6.0×10^2	[Endogenous material]	8.9 µl H_2/mg dry wt/hr
6	Chromatium sp	30 µl cells/ml	1.8 ml	30	Tungsten lamp	Optimal	[Endogenous material]	510 µl H_2/7.5 hr
7	Rhodopseudomonas gelatinosa	35 µl cells/ml	2.0 ml	30	Tungsten lamp	Optimal	[Endogenous material]	93 µl H_2/120 min
8							Acetic acid]	560 µl H_2/120 min
9							[Malic acid]	470 µl H_2/120 min
10	Rhodospirillum rubrum	25 µl cells/ml	2.0 ml	30	Tungsten lamp	Optimal	[Malic acid]	170 µl H_2/100 min
11		30 µl cells/ml					[Malic acid]	1275 µl H_2/20 hr
12		32 µl cells/ml					[Oxalacetic acid]	520 µl H_2/240 min
13	Scenedesmus obliques			25	Tungsten lamp	Optimal	[Endogenous material]	3.7 µl H_2/mg dry wt/hr
	Photochemical Oxidation of H_2: Photoreduction							
14	Chlorobium thiosulfatophilum	2.5 mg wet wt/ml	3.0 ml		Tungsten lamp	0.2	CO_2	45 µl H_2/hr
15						0.4		110 µl H_2/hr
16						0.6		185 µl H_2/hr
17	Scenedesmus, strain D3	18 µl cells/ml		21	Above 5500 Å	4.5×10^2	CO_2	43 µl H_2/10 min
	Photochemical Phosphorylation							
18	Chlorella pyrenoidosa	2.0 µl cells	20	20	Tungsten lamp	Saturation		3.5 x 10^{-5} µM P/ µl cells/sec
19	Chromatium, strain D	5 µl cells/ml	50 µl cells	29	Tungsten lamp	$1.2\text{-}1.3 \times 10^4$		2.4 µg P/120 min

Part III: PHOTOCHEMICAL REDUCTION: CELL-FREE PREPARATIONS

Data are photochemical reductions, with water as hydrogen donor (Hill reaction).

	Species	Amount mg[1]	Rate of Reaction[2] µl O_2/mg x hr
	Algae, Liverworts, Horsetails		
1	Chlorella pyrenoidosa	0.24	400
2	C. vulgaris	0.38	210
3	Conocephalum conicum	0.19	200
4	Equisetum arvense	0.83	240
5	E. scirpoides	1.60	700
	Spermatophytes: Grasses		
6	Barley (Hordeum vulgare)	1.80	540
7	Corn (Zea mays)	1.16	270
8	Millet (Panicum miliaceum)	0.71	2300
9	Oat (Avena sativa)	1.40	660
10	Rye (Secale cereale)	1.60	890
11	Wheat (Triticum aestivum)	1.14	760
	Spermatophytes: Broadleaf		
12	Bean (Phaseolus vulgaris)	0.48	370

	Species	Sample: Type	Sample: Unit	Total Sample	Radiant Energy: Type	Radiant Energy: Intensity[3]	H_2 Acceptor	Rate of Reaction µl O_2/min
27							p-Quinone	6.0
28	Spinach (Spinacea oleracea)	Granula	0.75-1.0 mg chlorophyll/ml	2 ml	Tungsten lamp	2.85 x 10^4	1, 2-Naphthoquinone-4-sulfonate	5.0
29							1, 4-Naphthoquinone-2-sulfonate	4.0
30							9, 10-Anthroquinone-4-sulfonate	1.5

[1] mg chlorophyll. [2] Data, expressed as µl O_2/mg chlorophyll/hr, are applicable to the following specifications: preparation, chloroplasts; hydrogen acceptor, $K_3Fe(CN)_6 + K_2C_2O_4$; radiant energy source, > 5350 Å; intensity, 4.8×10^4 erg/sq cm/sec. [3] erg/sq cm/sec.

233. NITROGEN FIXATION

Certain organisms fix atmospheric nitrogen in organic combination. Part I presents estimated amounts of nitrogen fixed per acre by symbiotic (rhizobia-legumes) and saprophytic bacteria. The amount of nitrogen fixed from the air by the symbiotic relation of rhizobia and legumes is influenced by effectiveness of the rhizobia, host species, soil and climatic conditions, and individual handling of the crop. Part II reveals strain and host specificity. Part III shows characteristics of various nitrogen-fixing organisms.

Part I: NITROGEN FIXING: BACTERIA, LEGUMES

	Organism	N Fixed Kg/acre
	Rhizobium spp - Legumes	
	Inoculated with Rhizobium melliloti	
1	Alfalfa (Medicago sativa)	88(25-170)
2	Burclover (M. denticulata)	35(23-49)
3	Fenugreek (Trigonella foenum-graecum)	37
4	Sourclover (Melilotus indica)	45
5	Sweetclover (M. alba)	54(30-75)
	Inoculated with R. trifoli	
6	Clover (Trifolium incarnatum)	42(32-53)
7	Clover (T. pratense)	52(19-78)
8	Clover (T. repens)	47(35-65)
9	Clover (T. repens giganteum)	81(72-91)
	Inoculated with R. leguminosarum	
10	Lentil (Lens culinaris & esculenta)	47
11	Pea (Pisum arvense)	23(20-28)
12	Pea (P. sativum)	33(13-60)
13	Vetch (Vicia spp)	36(20-63)
	Inoculated with R. phaseoli	
14	Bean (Phaseolus vulgaris)	18
	Inoculated with R. japonicum	
15	Soybean (Glycine soja)	26(7-48)
	Inoculated with R. lupini	
16	Lupine (Lupinus angustifolius)	68
	Inoculated with Rhizobium spp	
17	Cowpea (Vigna sinensis)	41(26-53)
18	Garbanzo (Cicer arietinum)	30
19	Kudzu (Pueraria thunbergiana)	49(40-57)
20	Lespedeza (Lespedeza striata& stipulacea)	39(15-94)
21	Peanut (Arachis hypogaea)	19
22	Velvetbean (Stizolobium deeringianum)	30
23	Pastures with legumes	48(5-91)
	Saprophytic Bacteria	
24	Azotobacter	12-17
25	Clostridium	1-2

Part II: NITROGEN FIXING: STRAIN-HOST RELATION

	Organism	N Fixed with Rhizobia Strains[1] mg/8 plants			
		RT 1	RT 16	RT 8	RT 13
1	Clover (Trifolium pratense)	54	34	3	2
2	Clover (T. repens)	60	46	10	7
3	Clover (T. subterranean)	8	7	138	154

/1/ Strains of Rhizobium trifolii. RT 1 isolated from Trifolium pratense; RT 16, from T. repens; RT 8 and 13, from T. subterranean.

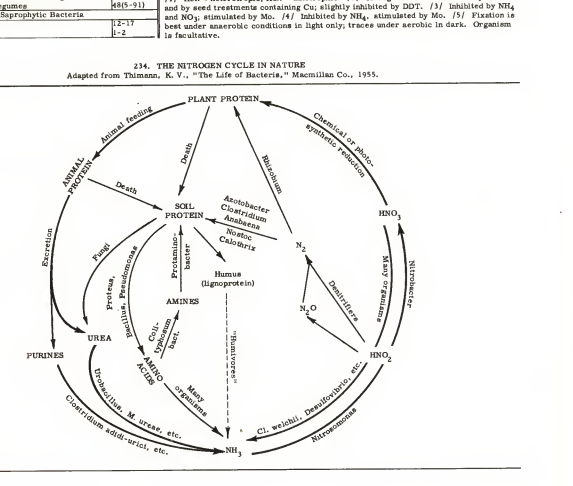
Part III: NITROGEN-FIXING: ORGANISMS

	Organism	Essential Symbiotic Relationship	O_2 Relation	Type[1]
	Rhizobium[2]			
1	R. meliloti[3]	Medicago, Melilotus	Aerobic	Het.
2	R. trifolii	Trifolium	Aerobic	Het.
3	R. leguminosarum	Pisum	Aerobic	Het.
4	R. phaseoli	Phaseolus	Aerobic	Het.
5	R. japonicum	Glycine	Aerobic	Het.
6	R. lupini	Lupinus	Aerobic	Het.
7	Various spp	Vigna, Lespedeza	Aerobic	Het.
8	Azotobacter[3]	None	Aerobic	Het.
9	Clostridium[4]	None	Anaerobic	Het.
10	Desulfovibrio	None	Anaerobic	Het.
11	Rhodopseudomonas and Rhodospirillum	None	Anaerobic[5]	Het.
12	Chromatium	None	Anaerobic	Aut.
13	Chlorobacterium	None	Anaerobic	Aut.
14	Rhodomicrobium	None	Anaerobic	Het.
15	Nostoc & Calothrix[3]	None	Aerobic	Aut.

/1/ Het. = heterotrophic; Aut. = autotrophic. /2/ Nitrogen fixation inhibited by 2, 4-D and by seed treatments containing Cu; slightly inhibited by DDT. /3/ Inhibited by NH_4 and NO_3; stimulated by Mo. /4/ Inhibited by NH_4, stimulated by Mo. /5/ Fixation is best under anaerobic conditions in light only; traces under aerobic in dark. Organism is facultative.

234. THE NITROGEN CYCLE IN NATURE

Adapted from Thimann, K. V., "The Life of Bacteria," Macmillan Co., 1955.



Products listed include only compounds (both diffusible and confined to the mycelium) produced on media containing glucose or sucrose, by the more common fungi (Mucor, Rhizopus, Aspergillus, Penicillium, Alternaria, Helminthosporium). The well-known antibiotics have been omitted. The organisms listed do not constitute the only species producing the compound but, for the most part, the more common ones or those used industrially. Most figures on yield are approximate, frequently based on weights of crude product or pure material after losses in purification. Yields may differ widely among strains of the same species.

	Metabolic Product	Produced By	Yield
		Organic Acids, Aldehydes, Alcohols and Related Compounds	
1	Acetaldehyde	Various Penicillia, Aspergilli, A. niger, Mucor species, and many other genera. By fixation with intercepting agents.	Up to 60% of theory when grown on sucrose with Aspergillus niger.
2	Acetic acid	Fomes annosus, Marasmius chordalis, Merulius confluens, M. lachrymans, M. niveus, M. tremellosus.	0.6% - 0.9% of glucose used for Merulius lachrymans and Marasmius chordalis.
3	Ascorbic acid	Aspergillus niger.	0.2% of the glucose consumed.
4	Clavacin[1] (claviformin or patulin)	Aspergillus clavatus, Penicillium expansum, P. claviforme, P. patulum.	2.2% of glucose added.
5	Citric acid	Citromyces, Penicillium luteum, P. citrinum, P. spimulosum, Aspergillus niger, A. clavatus, A. itaconicus, A. wentii, Mucor pyriformis, many other species. Commercial production on beet and cane molasses. Submerged production possible but not yet commercially successful.	As high as 90% of theory.
6	i-Erythritol	Penicillium brevi-compactum, P. cyclopium.	0.7% of the weight of the organism.
7	Ethyl acetate	Penicillium digitatum.	0.6% of the sugar consumed.
8	Ethyl alcohol	Fusarium species, Mucor species, Merulius species, various Penicillia and Aspergilli, Fomes annosus. Production much slower than by yeast.	Stoichiometric yield with Fusaria, Merulius species, Fomes annosus grown on hexoses and pentoses.
9	Formic acid	Aspergillus oryzae.	
10	Fumaric acid	Various species of Rhizopus; Aspergillus fumaricus, Penicillium griseofulvum, Caldariomyces fumago. Most species other than Mucorales give small amounts.	50% of theoretical yield after 30 days.
11	Fumigacin[1]	Aspergillus fumigatus, A. fumigatus mut. helvola.	0.02 - 0.15% of the glucose added.
12	Gentisyl alcohol	Penicillium patulum.	2.3% of the glucose added.
13	Gladiolic acid	Penicillium gladioli.	94 mg/liter of Raulin-Thom medium.
14	Gluconic acid	Penicillium chrysogenum, P. luteum, P. purpurogenum, Aspergillus species, Fusarium lini bolley.	Practically quantitative conversion in 24 hours.
15	Glucose	Aspergillus niger. From tartaric acid, lactic acid, mannitol and quinic acid.	
16	Glutaric acid	Aspergillus niger strains.	
17	Glycerol	Mucor racemosus, Aspergillus wentii, white Aspergilli, Clasterosporium and Helminthosporium.	Usually small amounts; some species, 3% of the glucose consumed.
18	Glycolic acid	Aspergillus niger (from acetate).	Traces.
19	Glycuronic acid	Ustulina vulgaris.	
20	Glyoxylic acid	Aspergillus niger (from acetate), Merulius lachrymans.	Traces.
21	Itaconic acid	Aspergillus terreus, A. itaconicus.	As high as 50% of theoretical yield.
22	Itatartaric acid	Aspergillus terreus mutant.	1.5% of glucose added.
23	Kojic acid	Aspergillus flavus - oryzae - tamarii group, A. wentii.	45-55% in 12 days. 63-66% reported.
24	α-Lactic acid	Practically confined to Mucorales. Various Rhizopus species, i.e., R. stolonifer, oryzae, japonicus, tritici, arrhizus. Fumaric acid produced by altering conditions.	Up to 62% with R. oryzae, 39-40% with R. japonicus.
25	Malic acid	White species of Aspergillus, A. flavus, Clasterosporium sp. Accompanied by succinic and fumaric acids.	Fair yields by submerged growths when growing at low temperatures.
26	Malonic acid	Penicillium funiculosum.	
27	Mannitol	White species of Aspergillus, many Aspergilli, Hyssochlamys fulva, Penicillium griseofulvum. Not produced from fructose.	45-50% of theory.
28	Meilein[2] (ochracin)	Aspergillus melleus, A. ochraceus.	300 mg/l of medium on sucrose.
29	Methyl glyoxal	Aspergillus niger. On hexasediphosphate.	16% of the substrate consumed.
30	Methyl salicylic acid	Penicillium griseofulvum, P. flexuosum.	2.4% of the glucose consumed.
31	Oxalic acid	Citromyces, Aspergillus, Penicillium and many other genera. Can be produced more economically by other methods.	50% of the sugar consumed.
32	Penicillic acid[1]	Penicillium cyclopium, P. puberulum, Aspergilli.	4.2% of the glucose consumed.
33	Propionic acid	Botrytis cinerea. On lactate.	
34	Pyruvic acid	Aspergillus niger (in presence of sodium sulfite as interceptor), Fusaria.	8.2% of the glucose consumed.
35	Saccharic acid	Aspergillus niger.	
36	Spiculosporic acid[3]	Penicillium spiculisporum, P. crateriforme, P. minio-luteum.	Approx. 2% of the sugar utilized.
37	Succinic acid	Mucor stolonifer, Aspergillus terreus, Ustulina vulgaris, Penicillium aurantio-virens, P. spiculosporum, Fusarium oxysporum, F. heterosporum, F. lini bolley, Fomes annosus, Merulius confluens, M. niveus, M. tremellosus.	Yields very small, except for Fusarium species.
38	Ustic acid	Aspergillus ustus.	0.6% of glucose added.
		Pigments	
39	Alboleersin (colorless)[4]	Helminthosporium leersii.	0.4% of mycelial weight.
40	Aurofusarin	Fusarium culmorum, F. graminearum.	Up to 4.4% of mycelial weight.
41	Auroglaucin	Aspergillus glaucus sp.	More than 13% of the dry growth.
42	β-Carotene	Neurospora, Mucor hiemalis, Phycomyces blakesleanus.	Traces.
43	γ-Carotene	Allomyces species.	Traces.
44	Carviolacin	Penicillium roseopurpureum (P. carminoviolaceum).	3.0% of mycelium (crude pigment).
45	Carviolin	Penicillium roseopurpureum (P. carminoviolaceum).	3.0% of mycelium (crude pigment).
46	Catenarin[5] (1-hydroxyemodin)	Helminthosporium catenarium, H. gramineum, H. velutinum, H. tritici-vulgaris.	As much as 10% - 40% of the mycelial weight in Helminthosporium gramineum, 20% in H. catenarium.
47	Chrysogenin	Penicillium chrysogenum.	
48	Chrysophanic acid (chrysophanol)	Penicillium islandicum.	0.1% of dried mycelium.
49	Citrinin[1]	Penicillium citrinum, Aspergillus terreus.	3.4% of the sugar consumed.
50	Citromycetin	Citromyces glabrum (Penicillium frequentans group).	As much as 20% sugar metabolized.
51	Cynodontin[5]	Helminthosporium cynodontis, H. euchlaenae, H. avenae.	Up to 4.2% of mycelium.
52	Emodic acid	Penicillium cyclopium.	0.1% (as acetyl derivative) of glucose supplied.

/1/ Possesses antibiotic properties but is not in clinical use. /2/ Converted to methyl salicylic acid on KOH fusion. /3/ Related to minioluteic acid. /4/ Related to luteoleersin. /5/ Compare Items 46, 51, 59, and 78. Different species of Helminthosporium have different proportions of these pigments.

	Metabolic Product	Produced By	Yield
		Pigments (concluded)	
53	Ergoflavin	Sclerotium clavus.	
54	Erythroglaucin	Aspergillus glaucus group, 15 species.	0.25% of the mycelium (pure).
55	Flavoglaucin	Aspergillus glaucus.	More than 25% of the dry growth weight.
56	Fulvic acid	Penicillium griseofulvum, P. flexuosum, P. brefeldianum.	15-20% of the mycelium, 2.7% of the glucose consumed.
57	Fumigatin	Aspergillus fumigatus.	0.35% of the glucose consumed (crude material).
58	Fusarubin	Fusarium solani	On sucrose 25 mg/liter of medium.
59	Helminthosporin[5]	Helminthosporium gramineum, H. catenarium, H. tritici-vulgaris, H. cynodontis.	As much as 22% - 40% of the mycelial weight in H. gramineum.
60	ω-Hydroxyemodin	Penicillium cyclopium, P. citreo-roseum, P. cyaneo-fulvum.	0.1/ of glucose (tetraacetyl derivative) supplied.
61	Islandicin	Penicillium islandicum.	3% of the mycelium.
62	Javanicin	Fusarium javanicum.	0.05% of the glucose added (pure).
63	Luteoleersin[6]	Helminthosporium leersii.	1.8% of the mycelium.
64	Lycopersin	Fusarium lycopersici.	
65	Monascofiavin	Monascus purpureus.	
66	Monascorubrin	Monascus purpureus.	
67	Nalgiovensin	Penicillium nalgiovensis.	1% of dry mycelium.
68	Oosporein	Oospora colorans.	9.5% of the substrate added.
69	Oxy-javanicin	Fusarium javanicum.	0.02% of the glucose added (pure).
70	Penetrinic acid	Penicillium notatum.	
71	Penicillopsin	Penicillopsis clavariaeformis.	7.5% of the mycelium.
72	Phoenicin	Penicillium phoeniceum, P. rubrum (also Bacillus pyocyaneus).	1.2% (pure) of mycelium.
73	Physcion (Emodin monomethyl ether)	Aspergillus glaucus species.	0.65% of the mycelium (pure).
74	Ravenelin	Helminthosporium ravenelii, H. turcicum.	10% of the mycelium.
75	Rugulosin	Penicillium rugulosum.	
76	Solanione	Fusarium solani D_2 purple.	
77	Spinulosin (6-hydroxyfumigatin)	Penicillium spinulosum, P. cinerascens, Aspergillus fumigatus.	0.11% of the glucose consumed (A. fumigatus).
78	Tritisporin[5]	Helminthosporium tritici-vulgaris, Helminthosporium species.	1.4% of the mycelium.
		Chlorine-containing Compounds	
79	Caldariomycin	Caldariomyces fumago.	0.4% of the glucose consumed.
80	Erdin[7]	Aspergillus terreus.	0.6% of the sugar consumed.
81	Geodin[7]	Aspergillus terreus.	0.5% of the sugar consumed.
82	Griseofulvin[1]	Penicillium griseofulvum, P. janczewskii.	2% of the mycelium.
83	Nalgiolaxin[8]	Penicillium nalgiovensis.	0.18% of dry mycelium.
84	Sclerotiorine	Penicillium sclerotiorum.	2% of the mycelium.
		Polysaccharides	
85	Capreolinose[9]	Penicillium capreolinum.	
86	Glycogen[10] (red-brown I_2 color)	White species of Aspergillus, Penicillium digitatum.	
87	Gums	Oidium sp., Penicillium lactis, P. guttulosum, Monilia candida, Mucor racemosus.	38% on 10% mannose.
88	Levan[11]	Aspergillus sydowii.	(From sucrose only).
89	Lutelc acid (Luteose)[12]	Penicillium luteum.	10-12%.
90	Mold starch[10] (blue I_2 color)	Penicillium species.	
91	Mycodextran[10] (no I_2 color)	Penicillium expansum, Aspergillus niger.	2% of the growth.
92	Mycogalactan[13]	Aspergillus niger (produced along with Mycodextran).	
93	Polygalactose[13] (galactocoralose)	Penicillium charlesii.	Approx. 4% of the sugar consumed (crude).
94	Polymannose[14]	Penicillium charlesii.	Approx. 4% sugar consumed (crude).
95	Rugulose[13]	Penicillium rugulosum.	
96	Sclerotiose[10]	Penicillium sclerotiorum.	10% of the mycelial weight.
97	Varianose[15]	Penicillium varians.	Approx. 1% of the glucose consumed (crude material).
		Sterols and Lipids	
98	Ergosterol	Aspergillus niger, A. oryzae, Fusarium lycopersici, F. lini bolley, Helminthosporium avenae, H. ravenelii, H. velutinum, Lentinus lepideus, Penicillium expansum, P. puberulum.	0.13% - 1.7% of mycelium.
99	Ergosteryl palmitate	Penicillium brevi-compactum, P. italicum.	0.5% of the growth, 0.6% of the glucose consumed.
100	Fat	All organisms.	Various.
101	Lecithin	Aspergillus oryzae (spores).	
102	Lecithin and cephalin	Aspergillus sydowii.	0.43-0.73%.
103	Phosphatides	Aspergillus oryzae, A. sydowii, A. citromyces.	
104	Sterols	Aspergillus fischeri, Penicillium puberulum, Paecilomyces variotl, Fusaria.	0.13%-1.0% of the dry mycelium.
		Nitrogen-containing Compounds	
105	Adenine	Aspergillus niger.	0.05%.
106	Aspergillic acid	Aspergillus flavus.	1% of the carbohydrate added.
107	Betaine	Aspergillus oryzae (spores).	
108	Choline sulfate	Aspergillus sydowii (from hydrolysis of mycelium).	
109	Hypoxanthine	Aspergillus oryzae, Rhizopus japonicus.	
110	Lycomarasmin (asparagyl-glycylhydroxalanine)	Fusarium lycopersici.	110 mg/l of medium on glucose.
111	Stachydrine (a-methyl-proline-methyl betaine)	Aspergillus oryzae, Rhizopus japonicus.	
112	Thiamine	Fusarium lini bolley.	20 gammas/gram of mycelium.
113	Urea	Penicillium johannioli, Aspergillus niger, Rhizopus nigricans.	
114	Uric acid	Aspergillus oryzae (spores).	

/1/ Possesses antibiotic properties but is not in clinical use. /5/ Compare Items 46, 51, 59, and 78. Different species of Helminthosporium have different proportions of these pigments. /6/ Related to alboleersin. /7/ Geodin and erdin are closely related compounds. /8/ Mono-chloronalgiovensin. /9/ Hydrolysis yields mannose, glucose, galactose and mannonic acid. /10/ Hydrolysis yields glucose. /11/ Hydrolysis yields fructose. /12/ Hydrolysis yields β-glucose-malonic acid (2.1), demalonylated lutelc acid. /13/ Hydrolysis yields galactose. /14/ Hydrolysis yields mannose. /15/ Hydrolysis yields D-glucose, D-galactose and D-idose or L-altrose.

In columns B D F I K the following symbols are used: $\mu\mu$ = a millionth of a millionth (10^{-12}); μ = a millionth (10^{-6}); m = a thousandth (10^{-3}); M = million (10^{6}). Values in columns I J K are included only to indicate the order of magnitude of the metabolic activity of representative groups of organisms.

	Organism	Weight mg	Temperature[1] °C	Metabolic Rate: Calories[2] Cal/ind/hr[4]	Cal/kg/hr	Oxygen Consumption ml/ind/hr[5]	L/kg/hr	Respiratory Quotient[3]	Typical Estimates, Natural Soils: Number Per sq m	Mass g/sq m	Metabolism Cal/hr/sq m
	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)
1	Bacteria						250[6]		200-1200 MM	200-1200	330 m
2	Acetobacter						750[6]				
3	Azotobacter						25-75[6]				
4	Escherichia coli						7				
5	Sarcina lutea	1 mμ	20, 5	33 m μμ	33	7 μμ		0, 71			
6	Fungi									40-400	
7	Mycoderma sp	100 mμ	20, 0	0. 024 mμ	238	4, 9 mμ	49	(0, 82)			
8	Saccharomyces sp	180 mμ	20, 0	8, 7 μμ	48, 1	1, 8 mμ	10	(0, 82)			
9	Protozoa								100-500 M	38	21-32 m
10	Chaos chaos (ameba)	0. 05	22, 5	42-62 mμ	0, 8-1, 2	8, 6-12, 9 μ	0, 17-0, 25	(0, 82)			
11	Nematoda								0. 2-20 M	0, 7-17, 8	4-107 m
12	Monhystera	0, 2-0. 3	16, 0	1, 4-2, 2 μ	6, 1-8, 3	300-450 μ	1, 3-1, 7	0, 83			
13	Plectus	0. 5-1. 0	16, 0	2, 9-5, 8 μ	4, 8-6, 8	600-1200 μ	1-1, 4	0, 83			
14	Dorylaimus	0, 5-56	16, 0	1, 9-216 μ	2, 4-5, 3	400-45, 000 μ	0. 5-1, 1	0, 83			
15	Annelida								50-2000	1. 6	0, 5 m
16	Lumbricus terrestris (earthworm)	500	17-20	0, 14 m	0, 29	0, 03	0. 06	(0, 82)			
17		5000	20-23	1, 4 m	0, 29	0, 3	0. 06	(0, 82)			
18		1200	13, 0	0, 42 m	0, 35	0. 09	0. 07	(0, 82)			
19	Mollusca								0-8500	0-50	0-15 m
20	Helix aspersa (garden snail)	10, 000	10, 0	2, 1 m	0, 21	0, 43	0. 04	(0, 82)			
21		10, 000	20, 0	4, 2 m	0, 42	0. 88	0. 09	(0, 82)			
	Arthropoda										
22	Crustacea								0-200	0-1. 2	0-2. 4 m
23	Talorchestia megalophalma	120	12-13	0, 1 m	0, 87	0, 02	0. 18				
24		390	12-13	0, 16 m	0, 40	0, 03	0. 08				
25		110	22-23	0, 18 m	1, 6	0, 04	0. 34	(0, 82)			
26		270	22-23	0, 28 m	1, 0	0. 06	0. 22				
27	Acari (mites)									4. 5	6, 7 m
28	Oribatei								2000-120, 000	0. 07-0. 8	0. 1-1. 2 m
29	Eustes sterrimus	0, 25	14, 5	150-190 mμ	0. 6-0. 8	30-40 μ	0. 12-0. 16	(0, 82)			
30	Notaspis coleoptratus	0. 03	11, 3	48 mμ	1. 6	10 μ	0. 33	(0, 82)			
31	Parasitiformes								200-7400	0. 09-0. 2	0. 1-0. 3 m
32	Macrocheles sp	0. 25	12, 0	480 mμ	1. 9	100 μ	0. 4	(0, 82)			
33	Aranese (spiders)								175-640	0. 64	0. 4-1. 4 m
34	Lycosa sp	15, 1	13, 0	33 μ	2. 2	6900 μ	0. 45	(0, 82)			
35	Opiliones								1. 6-38	0. 005-0. 15	0. 02-0. 5 m
36	Nemastoma sp	3. 8	13, 0	9. 2 μ	2. 4	1900 μ	0. 5				
	Insecta										
37	Collembola								40-40, 000	6. 8	27-46 m
38	Pogonognathus plumbens	1, 3-2, 5	13, 0	6, 5-9, 3 μ	3, 7-5, 0	1400-1900 μ	0. 77-1. 0				
39	Orchesella flavescens	1, 8-3, 5	13, 0	5, 3-11, 7 μ	2, 9-3, 3	1100-2400 μ	0, 61-0, 69				
40	Diptera									1, 0	1, 3 m
41	Tipula sp (larva)	275	13, 0	285 μ	1. 0	0. 06	0. 21	(0, 81)			
42		605	13, 0	500 μ	0. 82	0. 1	0. 17	(0, 82)			
43	Coleoptera									3. 8	6, 1 m
44	Carabus nemoralis (ground beetle)	645	13, 0	765 μ	1. 2	0. 16	0. 25	(0, 82)			
45	Epaphius secalis (ground beetle)	1, 2-2, 2	13, 0	7-9, 8 μ	5, 9	1, 5-2, 0 m	1. 2	(0, 82)			
46	Notiophilus biguttatus (ground beetle)	7, 5	13, 0	36 μ	4. 8	7. 6 m	0. 88	(0, 82)			
47	Staphylinus oleus (rove beetle)	245	13, 0	285 μ	1. 1	0. 06	0. 24	(0, 82)			

/1/ Temperature used in determining values in columns D-G. Values in column K are reduced to the common standard of 16°C according to Krogh's curve. /2/ Kilocalories. /3/ CO_2 liberated ÷ O_2 consumed. Values in parentheses are assumed. /4/ Kilocalories per individual per hour. /5/ Milliliters per individual per hour. /6/ Assuming a water content of 75% of the fresh weight.

This table lists only a few of the vast number of microbial reactions that are known, and is merely representative of types of processes used commercially. Most processes are patented; and recent information on yields and process modifications is not generally available. Industry is continually seeking better yielding strains of microorganism through selection and mutation.

Part I: GENERAL ORGANIC COMPOUNDS

	Product	Microorganism	Substrate[1]	Type of Culture[1]	pH	Temp °C	Time da	Yield	Industrial Uses
1	Acetone-butanol	Clostridium saccharoacetobutylicum, and others	Molasses diluted to 5-7% sugar, with addition of NH_3 compounds and $CaHPO_4$ as required.	Anaer.	5.0-7.0	29-34	1.7-2	28-33% mixed solvents (sugar basis); 74% butanol, 23% acetone, 4% ethanol.	Solvents; chemical manufacturing.
2	2, 3-Butanediol	Bacillus polymyxa; Aerobacter aerogenes	Grain mash, or starch plus nutrients, or sugars plus nutrients.	Preferably aer.	6.2	33	1.3-3	26-30% weight of carbohydrates.	Solvent; humectant; chemical intermediate.
3	Dihydroxyacetone	Acetobacter suboxydans	5% glycerol, 0.5% yeast extract, 0.25% KH_2PO_4.	Aer., sub. or surf.	5.5-7.0	28-30	3-10	90% of theory.	Fine chemical.
4	Ethanol	Saccharomyces cerevisiae	Molasses diluted to 12% sugar. Amm. sulfate or phosphate added as nutrients.	Aer. in early stages only	4.0-4.5	21-35	2.1	90% of theory based on fermentable sugar.	Solvent; fuel; chemical intermediate.
5	Glycerol	S. ellipsoideus var. Cal. wine yeast; S. cerevisiae	Molasses diluted to 17.5-20% sugar. Soda ash to 5% of mash added during fermentation.	Aer. in early stages only	7-8	30-32	5	20-25% of theory based on fermentable sugar.	Solvent; explosives, drugs and cosmetics; humectant.
6	Citric acid	Aspergillus niger, or A. wentii	10-20% sucrose, or purified molasses mashes plus nutrients.	Sub., aer. or surf.	3.0-4.1	25-30	3-10	60-90% based on sugar.	Food products, medicinal citrates; in blood for transfusion.
7	Fumaric acid	Rhizopus nigricans	5-10% invert sugar, plus nutrient salts and $CaCO_3$.	Sub., aer.	5-6	33	4	58-64% based on sugar utilized.	Manufacture of alkyd resins, wetting agents.
8	Gluconic acid	Aspergillus niger, strain 67	Corn sugar, $MgSO_4 \cdot KH_2PO_4$, $(NH_4)_2HPO_4$, $CaCO_3$. Glucose conc. 15.2 g/100 ml.	Sub., aer.	5.0	30	1	93-97% based on glucose utilized.	Pharmaceutical products.
9	2-Keto-gluconic acid	Pseudomonas spp	Glucose, gluconic acid.	Aer.	4.5-7	30-35	1.4-1.5	90%.	Intermediate for a-araboascorbic acid.
10	5-Keto-gluconic acid	Acetobacter suboxydans	Glucose.	Aer.	4.5-7	30-35	1.5-2.5	90-95%.	Intermediate for tartaric acid.
11	Itaconic acid	Aspergillus terreus	6.6-27.5% glucose or sucrose (molasses) plus $(NH_4)_2SO_4$. $MgSO_4$, corn steep liquor	Sub. or surf., aer.	1.8-2.2	35	2-3	38-60% based on sugar.	Manufacture of alkyd resins, wetting agents.
12	Kojic acid	A. flavus	Sugars plus mineral nutrients.	Aer.	2.0-3.5	29-35	12	45-60% based on sugar.	No uses developed.
13	Lactic acid	Lactobacillus delbruckii	Acid hydrolyzed corn starch or whey, plus nutrients and $CaCO_3$.	Anaer.	5.5-6.5	45	5-10	93-94% based on sugar.	Food products, textile and laundry, chem. mfg., deliming hides.
14	Bacitracin(s)	Bacillus licheniformis	Dextrose, sucrose or starch, plus soybean or peanut meal or other protein.	Sub., aer.	6.2-7.7	37	2-3	1.5 grams per liter.	Active against Gram-pos. bacteria topically.
15	Carbomycin (Magnamycin)	Streptomyces baletedii	Media of organic composition.	Sub., aer.	6-8		3-5	100 mg per liter.	Active against some Gram-pos. bact., rickettsia, large viruses.
16	Chloramphenicol (Chloromycetin)	S. venezuelae	1% maltose, 0.5% casamino acids, 0.5% distillers' solubles, 0.5% NaCl.	Sub., aer.	6.7	23-27	3-6	170 mg per liter.	Same as aureomycin.
17	Chlortetracycline (Aureomycin)	S. aureofaciens	0.5-5.0% starch or monosaccharoses; amino acids, casein, fish meal, soybean meal, ures, nitrates, NH_3 compounds or corn steep liquor; inorg. salts of K, Ca, Mg, Fe, S, Cu, Mn, and Zn.	Sub., aer.	6.0-7.0	26-28	1-3	500-1300 mg per liter.	Effective orally against Gram-pos. and some Gram-neg. bacteria, some rickettsia and some viruses.
18	Cycloheximide (Actidione)	S. griseus	Glucose, salts, soybean meal, and butyl fermentation residue.	Aer.	6-8	24	3-5	80-250 mg per liter.	Antibiotic: yeasts, fungi, esp. plant disease fungi.
19	Erythromycin (Ilotycin)	S. erythreus	Glucose, soybean meal, corn steep liquor.	Sub., aer.	6.4-7.2	26-30	3-5	350 mg per liter.	Same as aureomycin.
20	Fumagillin (Phagopedin Sigma)	Aspergillus fumigatus	Dextrin and corn steep liquor.	Sub., aer.	6.5-7.5		1.5-4	300 mg per liter.	Amebicide.
21	Neomycin (complex)	Streptomyces fradiae	Glucose, soya peptone, meat extract, NaCl, $ZnSO_4$.	Sub., aer.	6.5-6.8	24-30	3.8-6	2-3 grams per liter.	Active against Gram-pos. and Gram-neg. bacteria.
22	Oxytetracycline (Terramycin)	S. rimosus	Soybean meal, starch, casein digest, salts.	Sub., aer.	7.0-8.0	24-30	2	>1 gram per liter.	Broad spectrum antibiotic.
23	Penicillin	Penicillium chrysogenum Q176 or derived mutants	Corn steep liquor, lactose, dextrose, animal or vegetable oil, salts, phenylacetic acid.	Sub., aer.	5.5-7.5	23-25	2-6	1000-3000 International Units per ml.	Active against many Gram-pos. organisms.
24	Polymyxins	Bacillus polymyxa	Glucose, yeast extract, salts.	Sub., aer.	6.3-7.9	25	5	163-358 units polymyxin D per ml.	Active against Gram-neg. bacteria.
25	Streptomycin	Streptomyces griseus[2]	Glucose, soybean meal, corn steep liquor, NaCl, and animal or vegetable oil.	Sub., aer.	6.0-7.5	24-30	3-6	150-900 mg per liter.	Active against many bacteria, particularly Myco. tuberculosis.
26	Viomycin (Vinactin)	S. floridae or S. puniceus	Glucose, hydrolyzed casein, yeast hydrolysate, salts.	Sub., aer.	6.0-8.0	24-26	3-6	600 mg per liter.	Active against Myco. tuberculosis.
27	Bacterial amylase	Bacillus subtilis	Vegetable protein plus sugar for surf.; starch, cereal grain and protein for sub.	Surf., aer., or sub., aer.	6.5-7.0	30-40	1-3	400-500 grams amylase concentrate from 100 liters culture.	Modified starches; sizing paper; desizing textiles.

28	Bacterial protease	B. subtilis	1% protein, 6% carbohydrate, salts.	Surf., aer.	6.5-7.0	37	3-5		Bating hides; desizing fibers; spot remover; tenderizing meat.
29	Pectinases	Aspergillus wentii or A. aureus (Nakazawa)	1000 kg bran plus 800 liters H_2O. Inoculate with 100 liters spore suspension.	Aer.		33-37	2-3	Aqueous extract of culture adsorbed on bran from coffee bean husk.	Clarifying agents in fruit juice industries.
30	11-γ-Hydroxyprogesterone	Rhizopus arrhizus, R. nigricans, others	Progesterone, plus lactalbumin digest, corn steep liquor, glucose.	Aer.	4.4-6	24-28	2-3	10-95%.	Intermediate for 17-γ-hydroxycorticosterone.
31	Dextran	Leuconostoc mesenteroides	Sucrose plus nutrients.	Anaer.		20-30	1-5	10-40% of sucrose used.	Stabilizer in food products; blood plasma substitute.
32	Sorbose	Acetobacter suboxydans	25% sorbitol plus yeast extract or corn steep liquor.	Aer., sub., or surf.	5.1-6.8	28-30	3-10	90-95% of theory.	Manufacture of ascorbic acid.
33	Cobalamin	Streptomyces olivaceus; Propionbacterium freudenreichi.	Distillers' solubles, dextrose, $CaCO_3$, $CoCl_2$.	Sub., aer. agitation.	6.5-8.0	27-29	3-5	1.2 mg per liter, average.	Pernicious anemia; food and feed supplementation.
34	Ergosterol	Saccharomyces carlsbergensis	Saccharine materials with nutrients.	Aer.	7.0-7.5	25	1-2	2-2.7% of weight of yeast.	Manufacture vitamin D.
35	Riboflavin[3]	Eremothecium ashbyii, Ashbya gossypii, and others	For E. ashbyii, carbohydrates and protein; for A. gossypii, glucose, corn steep and animal steep liquor.	Sub., aer.	4.5-7.5	27-30	5-10	0.5-2.5 grams per liter.	Food and feed supplementation.

/1/ Sub.=submerged culture; surf.=surface culture; aer=aerobic; anaer.=anaerobic. /2/ Improved strains obtained by exposing organism to UV light or nitrogen mustard. /3/ See U.S. Patent 2,605,210.

Part IB. FOODS AND BEVERAGES

	Product	Microorganism	Method of Preparation	Factors Influencing Reaction	Function of Microorganism
1	Acidophilus milk Cheese	Lactobacillus acidophilus	Fresh, whole milk sterilized at 120°C for 15 min is cooled and inoculated with the organism.	Microaerophilic, pH 6.6, 35-37°C, 20-48 hr.	Produces lactic acid from milk sugar[1].
2	Camembert and Brie types	Penicillium camemberti	Curd cut into cakes 3-4 cm thick, containing 55-60% H_2O and salted on surface.	4 wk at 10-16°C, in a ripening room at 88% relative humidity.	Mold grows on cheese surface, gradually softening whole mass of curd.
3	Roquefort and Gorgonzola types	P. roqueforti	Raw curd pressed to leave irregular cracks and channels; inoculated with mold grown on bread.	Partially aerobic. Aerated during ripening at 9°C by piercing with wires.	Produces caproic, capeylic, other acids imparting characteristic flavor.
4	Pickles	Mixed natural lactic acid organisms, including Lactobacillus plantarum	Cucumbers in tanks allowed to undergo spontaneous lactic fermentation in salt brine. For dill pickles, dill spices added before fermentation. For others, salt is leached, and pickles packed with vinegar, sugar, spices, etc.	Salt concentration and availability of O_2 affect rate and kind of fermentation. Optimum temp is 21-27°C.	Converts fermentable substances, forming particularly lactic acid. Final titratable acidity, as lactic acid, 0.5-1.0%, pH = 3.5-3.8.
5	Sauerkraut	Same as for pickles	Shredded cabbage placed in vats with salt. Undergoes spontaneous lactic fermentation.	Anaerobic fermentation. Optimum temp 16-24°C.	Converts fermentable substances into lactic acid, mainly, plus acetic acid and ethanol. Final acidity, as lactic, 1.5-2.0%.
6	Vinegar	Acetobacter aceti, A. pastorianum and other Acetobacter spp	Alcoholic solutions (e.g., wine, cider) derived from fermentation of grapes, apples, or grain are "acetified" by acetic acid bacteria.	Aerobic requiring 8-10 da at 28-40°C, or less depending on process conditions.	Alcohol oxidized to acetic acid, 5% acid being formed from approximately 5% alcohol.
7	Yeast, bakers'	Saccharomyces cerevisiae (selected baker's' strains)	Molasses solutions with ammonium salts, phosphates, and Mg salts seeded with pure yeasts strains. Increments of medium added frequently as nutrients are exhausted.	Very vigorous aeration throughout process. pH 3.4-4.5. Temp 24-30°C. Growth complete in 11 hr.	Converts 100 parts molasses to equivalent of 100 parts pressed yeast (27% dry matter).
8	Beer	S. cerevisiae or S. carlsbergensis	Barley malt and starch adjuncts mixed with warm water. After enzymic starch conversion, wort is filtered, then boiled with hops, and finally fermented with yeast.	Aerobic in early stages, but quickly becomes anaerobic. Temp 8-12°C?. pH at start 5.0-5.4; at end 4.0-4.6. Primary fermentation lasts 5-9 da.	Converts sugar into alcohol and CO_2; produces changes in proteins and other minor constituents which modify flavor.
9	Rum	S. cerevisiae or other yeasts	Blackstrap molasses containing 12-14% fermentable sugar. Ammonium sulfate and occasionally phosphates may be added as nutrients. Distilled after fermentation.	Optimum pH 4.0-4.7. Initial temp 21°C rising to final temp of 35.5. Fermentation lasts 3-7 da.	Sugar converted to alcohol which is then removed by distillation.
10	Whisky, Scotch	S. cerevisiae (generally a top yeast)	Grain mash cooked, saccharified with peated malt and fermented. Batch distilled and distillate aged in oak casks at least 3 yr; then blended with grain whiskey.	Optimum pH 4.0-5.0. Initial temp 26°C. Fermentation completed in 72 hrs.	Produces alcohol and congeneric substances (acids, esters, various alcohols) which with the peated malt give characteristic Scotch flavor.
11	Whiskey, bourbon	S. cerevisiae	Grain mash consistency of corn (at least 51%); generally with rye, cooked and saccharified with malt and fermented. Distillate, between 110-130° proof, matured in charred oak barrels.	Same as for Scotch whisky.	Same as for Scotch whisky, but the flavor is characteristic of bourbon whiskey.
12	Wine	S. ellipsoideus, various strains	Grape must with sugar concentration up to 22° Balling is sulfited to reduce rate of fermentation. Allowed to ferment with special strain of yeast, or with yeast naturally present on the grape. Primary fermentation succeeded by a period of storage for maturation.	Aerobic in early stages, but mainly anaerobic later. Temp below 29.4° C, but varies according to local conditions, yeast strain, and type of wine. Fermentation lasts 7-11 da.	Converts sugar into alcohol, and also produces changes in minor constituents which modify flavor and bouquet. Amount of alcohol varies according to type of wine.

/1/ Lactic acid plus large quantities of organism produced are used for various disorders of the gastrointestinal tract. /2/ 14-20°C with S. cerevisiae.

	Animal	Stage	Approximate Age		Body Weight kg		Body Surface Area[1] sq m		Resting Metabolism[2] Cal/kg/da		Resting Metabolism[2] Cal/sq m/da		Oxygen Consumption liters/kg/da		Basal Metabolism Cal/kg/da		Basal Metabolism Cal/sq m/da		Oxygen Consumption liters/kg/da	
			♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1	Man	Adult			65	56	1.83	1.65							25.5	23.2	910	790		
2	Baboon	Adult			6.2		0.40								48		760			
3		Young		1.8 mo	70	60	1.4	1.3	43.8	51.1	2190	2385	9.1	10.6						
4	Beef cattle	Half-grown		11 mo	300	250	3.2	2.9	25.6	26.3	2420	2295	5.3	5.5		18.2		1595		3.8
5		Adult		1.7 yr	500	400	4.2	3.7	21.2	21.1	2515	2270	4.4	4.4		15.2		1635		3.2
6	Cat	Adult			3.0		0.2								50		750			
7	Chimpanzee	Adult			38		1.1								29.2		980			
8		Young		6 mo		150		2.4		34.4		2100		7.1						
9	Dairy cattle	Half-grown		1.2 yr		300		3.6		26.0		2170		5.4						
10		Adult		2 yr		500		5.0		21.1		2180		4.4						
11	Dog	Adult			15.5	11.7	0.65	0.58							33.5	38.5	800	770		
12	Elephant	Adult			3670		23.8								13.3		2060			
13	Elephant, small	Adult			1360		13.7								11.8		1170			
14		Young			2				130	125										
15	Goat	Half-grown			20				63	54										
16		Adult			70				42	34										
17		Young		30 da	0.2		0.029		115	120	780	805	23	24	110	110	735	765	23	24
18	Guinea pig	Half-grown	82 da	87 da	0.4		0.046		90	95	800	825	29	19	85	90	755	790	18	19
19		Adult	290 da	270 da	0.8		0.071		63	68	710	765	13	14	60	63	675	710	13	13
20		Young	2.8 mo	2.9 mo	200		2.8		32.2	32.7	2280	2320	6.7	6.8						
21	Horse	Half-grown	9.5 mo	8.5 mo	350		4.0		24.6	25.3	2150	2210	5.0	5.2						
22		Adult	4.2 yr	2.8 yr	650		5.9		25.2	24.7	2770	2710	5.2	5.1						
23	Macaque	Adult			4.2		0.31								49.3		675			
24	Marmot	Adult			2.6		0.18								28.3		420			
25	Monkey, rhesus	Adult			3.2		0.26								48.4		610			
26	Mouse, albino	Adult			0.02		0.005								170		525			
27	Mouse, dwarf	Adult			0.008		0.0064								125		260			
28	Mouse, obese	Adult			0.06		0.01								130		550			
29		Young		4 mo	200		2.9		39.2		2700		8.1							
30	Mule	Half-grown		13 mo	400		4.5		30.6		2705		6.3							
31		Adult		38 mo	600		5.8		26.4		2710		5.5							
32	Pony, shetland	Adult			280		4.4								16.7		1060			
33	Rabbit	Adult			3.5		0.2								47		810			
34		Young		29 da	0.05		0.013		280		1085		60		240		930		51	
35	Rat	Half-grown	50 da	60 da	0.15		0.026		195	165	1120	970	39	34	160	155	930	890	34	33
36		Adult	60 da	120 da	0.2		0.031		155	135	1000	870	32	28	140	120	905	760	30	25
37	Sheep	Adult			49.5	42.7	1.10	0.95							26.3	25.7	1180	1160		
38		Young	9.4 mo	8.3 mo	75		1.5		37.3	40.5	1880	2040	7.7	8.4	30.9	30.2	1550	1520	6.4	6.3
39	Swine	Half-grown	1.3 yr	1.1 yr	190		2.3		28.9	25.1	1880	1625	6.0	5.2	21.9	18.7	1420	1210	4.5	3.9
40		Adult		2.1 yr	250		3.2		23.7	17.8	1860	1390	4.9	3.7	17.4	14.1	1360	1100	3.6	2.9
41	Birds, wild	Adult			3.0		0.2								57		830			
42	Canary	Adult			0.016		0.006								310		760			
43		Young		4 wk	0.25	0.2	0.04	0.03	195	210	1220	1230	40	43						
44	Chicken	Half-grown		13 wk	1.1	0.9	0.11	0.1	105	100	1020	900	21	20	90	90	870	830	19	19
45		Adult		25 wk	2.6	2.0	0.21	0.17	95	75	1160	880	19	16	85	70	1075	800	18	15
46	Dove, ring	Adult			0.15		0.03								130		700			
47	Duck	Adult			0.3		0.1								90		855			
48	Goose	Adult			5.0	3.3	0.29	0.23							54	61	940	880		
49	Parakeet	Adult			0.03		0.009								225		690			
50	Pigeon	Adult			0.28		0.06								100		670			
51	Lizard				1.2		0.11								2.5		29			
52	Turtle				0.14		0.02								11.4		64			
53	Frog				to 0.05												130			
54	Toad				to 0.05												130			
55	Fish				to 0.25												33			
56	Fish, sturgeon				1400		11.8								0.3		31			

/1/ Surface area in sq m calculated from $k \times W^{0.67}$, or, in sq cm, from the following equations (W=body weight in grams): man, $3.81\ W^{0.425} \pm H^{0.725}$ (where H=height in cm); baboon, $11.7\ W^{0.667}$; chimpanzee, $10\ W^{0.667}$; dog, $11.2\ W^{0.667}$; guinea pig, $9.85\ W^{0.64}$; monkey, rhesus, $11.7\ W^{0.667}$; mouse, $15.15\ W^{0.458}$; rabbit, $56.33\ W^{0.435}$; sheep, $8.5\ W^{0.667}$; chicken, $8.19\ W^{0.705}$; reptiles, amphibians, fish, $9\ W^{0.67}$. Surface area in sq m (W=body weight in kg): beef cattle, $0.13\ W^{0.56}$; dairy cattle, $0.15\ W^{0.56}$; horse, $9.1\ W^{0.63}$; mule, $0.1\ W^{0.633}$; rat, $0.0011\ W^{0.63}$; sheep, $0.097 W^{0.633}$. (W in grams); swine, $0.097 W^{0.633}$.

/2/ Resting metabolism refers to heat production when animal is at rest, although neither in a strictly thermo-neutral environment, nor in a post-absorptive state. Cattle, goats, swine, and chickens were measured in a recumbent position. Resting metabolism, as thus defined, is considerably greater than basal metabolism, exact values depending on nature of diet, time after feeding, and environmental temperature.

239. BASAL METABOLISM: MAN

Values are smoothed means of basal Calories per sq m per hr from the three largest and most suboritative sets of original data, representing a total of 4016 measurements. The three sets of data used are: (1) The Mayo Foundation Standards of Boothby, Berkson and Dunn, based upon 639 males and 828 females; (2) the British measurements of Robertson and Reid, based upon 987 males and 1323 females; (3) The Carnegie Nutrition Laboratory data of Harris and Benedict, based upon 136 males and 103 females. The height-weight formula of DuBois and DuBois was used in computing the sq m of body surface area: $SA = 0.007184 \times W^{0.425} \times S^{0.725}$, where SA is the surface area in square meters, W is the body weight in kilograms and S is the height in centimeters. Ranges, given in parentheses, are calculated from an average coefficient of variation[1] of 6.9% and represent estimate "b" of the 95% range. Somewhat higher values are to be expected on first tests (i. e., on persons not accustomed to the procedures). For comparison of these standards with previous American and other important standards, see table below.

	Age yr	Males Cal/sq m/hr	Females Cal/sq m/hr		Age yr	Males Cal/sq m/hr	Females Cal/sq m/hr
1	Three	60. 1 (51. 8-68. 3)	54. 5 (47. 0-62. 0)	24	Twenty-six	38. 2 (32. 9-43. 5)	35. 0 (30. 2-39. 8)
2	Four	57. 9 (49. 9-65. 9)	53. 9 (46. 5-61. 3)	25	Twenty-seven	38. 0 (32. 8-43. 2)	35. 0 (30. 2-39. 8)
3	Five	56. 3 (48. 5-64. 1)	53. 0 (45. 7-60. 3)	26	Twenty-eight	37. 8 (32. 6-43. 0)	35. 0 (30. 2-39. 8)
4	Six	54. 0 (46. 5-61. 5)	51. 2 (44. 1-58. 3)	27	Twenty-nine	37. 7 (32. 5-42. 9)	35. 0 (30. 2-39. 8)
5	Seven	52. 3 (45. 1-59. 5)	49. 7 (42. 8-56. 6)	28	Thirty	37. 6 (32. 4-42. 8)	35. 0 (30. 2-39. 8)
6	Eight	50. 8 (43. 8-57. 8)	48. 0 (41. 4-54. 6)	29	Thirty-one	37. 4 (32. 2-42. 6)	35. 0 (30. 2-39. 8)
7	Nine	49. 5 (42. 7-56. 3)	46. 2 (39. 8-52. 6)	30	Thirty-two	37. 2 (32. 1-42. 3)	34. 9 (30. 1-39. 7)
8	Ten	47. 7 (41. 1-54. 3)	44. 9 (38. 7-51. 1)	31	Thirty-three	37. 1 (32. 0-42. 2)	34. 9 (30. 1-39. 7)
9	Eleven	46. 5 (40. 1-52. 9)	44. 1 (38. 0-50. 2)	32	Thirty-four	37. 0 (31. 9-42. 1)	34. 9 (30. 1-39. 7)
10	Twelve	45. 3 (39. 0-51. 6)	42. 0 (36. 2-47. 8)	33	Thirty-five	36. 9 (31. 8-42. 0)	34. 8 (30. 0-39. 6)
11	Thirteen	44. 5 (38. 4-50. 6)	40. 5 (34. 9-46. 1)	34	Thirty-six	36. 8 (31. 7-41. 9)	34. 7 (29. 9-39. 5)
12	Fourteen	43. 8 (37. 8-49. 8)	39. 2 (33. 8-44. 6)	35	Thirty-seven	36. 7 (31. 6-41. 8)	34. 6 (29. 8-39. 4)
13	Fifteen	43. 7 (37. 7-49. 7)	38. 3 (33. 0-43. 6)	36	Thirty-eight	36. 7 (31. 6-41. 8)	34. 5 (29. 7-39. 3)
14	Sixteen	42. 9 (37. 0-48. 8)	37. 7 (32. 5-42. 9)	37	Thirty-nine	36. 6 (31. 5-41. 7)	34. 4 (29. 7-39. 1)
15	Seventeen	41. 9 (36. 1-47. 7)	36. 2 (31. 2-41. 2)	38	Forty	36. 5 (31. 5-41. 5)	34. 3 (29. 6-39. 0)
16	Eighteen	40. 5 (34. 9-46. 1)	35. 7 (30. 8-40. 6)	39	Forty-five	36. 3 (31. 3-41. 3)	33. 9 (29. 2-38. 6)
17	Nineteen	40. 1 (34. 6-45. 6)	35. 4 (30. 5-40. 3)	40	Fifty	36. 0 (31. 0-40. 0)	33. 4 (28. 8-38. 0)
18	Twenty	39. 8 (34. 3-45. 3)	35. 3 (30. 4-40. 2)	41	Fifty-five	35. 4 (30. 5-40. 3)	32. 9 (28. 4-37. 4)
19	Twenty-one	39. 4 (34. 0-44. 8)	35. 2 (30. 3-40. 1)	42	Sixty	34. 8 (30. 0-39. 6)	32. 4 (27. 9-36. 9)
20	Twenty-two	39. 2 (33. 8-44. 6)	35. 2 (30. 3-40. 1)	43	Sixty-five	34. 0 (29. 3-38. 7)	31. 8 (27. 4-36. 2)
21	Twenty-three	39. 0 (33. 6-44. 4)	35. 2 (30. 3-40. 1)	44	Seventy	33. 1 (28. 5-37. 7)	31. 3 (27. 0-35. 6)
22	Twenty-four	38. 7 (33. 4-44. 0)	35. 1 (30. 3-39. 9)	45	Seventy-five and above	31. 8 (27. 4-36. 2)	31. 1 (26. 8-35. 4)[2]
23	Twenty-five	38. 4 (33. 1-43. 7)	35. 1 (30. 3-39. 9)				

/1/ Coefficient of variation = 6. 9 = average of values from five sources. /2/ Value and range extrapolated from smoothed curve.

240. COMPARATIVE STANDARDS OF BASAL METABOLISM: MAN

Column F is the standard commonly employed heretofore in America. The underlying measurements include many first tests (on persons unaccustomed to the procedure). Values are accordingly high -- the highest of the standards. Values in column D, the British standard, are based on the lowest of repeated measurements on trained persons under rigorously basal conditions. Values in column E are based on measurements on well trained children and are generally the lowest of those given for children. Adult values in columns B and C are so similar that either standard can be used safely in clinical medicine. For children, choice between columns E or C and columns B or D will depend on the experience of the testing laboratory. Some laboratories tend to find higher basal values and some laboratories, lower. Each laboratory may accordingly develop its own standard. A variation of as much as 14% above or below the standard may occur in healthy persons (estimate "b" or "d" of the ordinary range).

	Age yr	Boothby[1] 1952 Cal/sq m/hr		Fleisch[2] 1951 Cal/sq m/hr		Robertson and Reid[3] 1952 Cal/sq m/hr		Lewis, Duval and Iliff, [4] 1943 Cal/sq m/hr		Boothby, Berkson and Dunn, [5] 1936 Cal/sq m/hr	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
	(A)	(B)		(C)		(D)		(E)		(F)	
1	Two			52. 4	52. 4			56. 9	52. 9		
2	Four	57. 9	53. 9	50. 3	49. 8	57. 9	53. 9	52. 6	49. 9		
3	Six	54. 0	51. 2	48. 3	47. 0	54. 2	51. 8	49. 6	46. 9	53. 0	50. 5
4	Eight	50. 8	48. 0	46. 3	43. 8	50. 1	48. 4	46. 6	44. 0	51. 5	46. 7
5	Ten	47. 7	44. 9	44. 0	42. 5	46. 6	44. 3	43. 6	41. 4	48. 0	45. 7
6	Twelve	45. 3	42. 0	42. 5	41. 3	43. 8	40. 6	41. 5	39. 7	46. 8	43. 9
7	Fourteen	43. 8	39. 2	42. 1	39. 2	41. 8	37. 8	41. 1	36. 8	46. 4	41. 1
8	Sixteen	42. 0	37. 2	41. 4	36. 9	40. 3	36. 0			45. 5	38. 6
9	Eighteen	40. 8	35. 8	40. 0	35. 9	39. 2	34. 9			42. 9	37. 0
10	Twenty	39. 9	35. 3	38. 6	35. 3	38. 4	34. 3			41. 6	36. 3
11	Twenty-five	38. 4	35. 1	37. 5	35. 2	37. 1	34. 0			40. 3	36. 0
12	Thirty	37. 6	35. 0	36. 8	35. 1	36. 4	34. 1			39. 6	35. 8
13	Thirty-five	36. 9	34. 8	36. 5	35. 0	35. 9	33. 5			38. 9	35. 7
14	Forty	36. 5	34. 3	36. 3	34. 9	35. 5	32. 6			38. 3	35. 5
15	Forty-five	36. 3	33. 9	36. 2	34. 5	34. 3[6]	32. 4[6]			37. 6	35. 3
16	Fifty	36. 0	33. 4	35. 8	33. 9	33. 9[6]	32. 1[6]			37. 0	34. 4
17	Fifty-five	35. 4	32. 9	35. 4	33. 3	33. 6[6]	31. 8[6]			36. 3	33. 4
18	Sixty	34. 8	32. 4	34. 9	32. 7	33. 2[6]	31. 4[6]			35. 7	32. 8
19	Sixty-five	34. 0	31. 8	34. 4	32. 2	32. 8[6]	31. 2[6]			35. 1[7]	32. 4
20	Seventy	33. 1	31. 3	33. 8	31. 7	32. 6[6]	30. 8[6]			34. 5[7]	32. 2
21	Seventy-five[8]	31. 8	31. 1[9]	33. 2	31. 3	32. 0	30. 5[9]			33. 4[7]	32. 0[7]

/1/ These are the values used in the top table; they are based on values in cols. D, F and values from Harris and Benedict, 1919. /2/ Based on values from 24 reports in the literature, including those in cols E, F, of this table and values from Harris and Benedict, 1919. /3/ The British standard. These values constitute part of the basis for those in col. B. /4/ These values constitute part of the basis for those in col. C. /5/ These values are part of the basis for those in cols. B and C. /6/ Interpolated. Original data given for pentades 40-44, 45-49, etc. /7/ Extrapolated by authors. /8/ Values are for age 75 or over. /9/ Extrapolated.

Oxygen consumed by tissue in a buffered medium is measured in a closed chamber at approximately 1 atm. pressure and at 37°C. Further definition of the medium is given in the key below; where only the substrate is named the medium contains that substrate in Ringer solution. The oxidation quotient ($-Q_{O_2}$) is expressed in cu mm O_2 per mg dry-weight tissue in one hour. A = serum; B = Ringer glucose; C = salin; D = Ringer phosphate; E = Ringer solution; F = horse serum; G = horse serum glucose[1]; H = glutamate; I = lactate; J = succinate; K = pyruvate; L = glucose; M = no substrate added; N = alanine; O = butyrate.

Tissue	Medium	$-Q_{O_2}$
Man		
1 Cerebral cortex	B	6.0-10.3
2 Decidua	A	2.5
3 Lung, embryo	B	3.7
4 Lymph nodes	B	3.8-5.9
5 Mucosa, gastric	B	9.6
6 Muscle, smooth, gastric	B	1.3
7 Uterine	B	0.6
8 Salivary gland	B	6.3
9 Skin, adult	B	2.1
10 Fetus	D	1.8
11 Sperm	D	0.54
12 Tonsil	B	5.1
Rat		
13 Adrenal	A	10.0
14 Brain cortex	D^2	26.3
15 Cerebral cortex	M	2.9
16 Cerebral cortex	L	10.8
17 Cerebral cortex	H	8.0
18 Cerebral cortex	I	13.6
19 Cerebral cortex	J	9.5
20 5 da	B	6.2
21 50 da	B	14.7
22 Adult	B	8.5-17.1
23 Chorion	B	13.5
24 Diaphragm	M	6.3[2]
25 Diaphragm	L	5.4
26 Diaphragm	I	9.4[3]
27 Diaphragm	K	6.3[4]
28 Embryo, 1-3 mg	A	10.5-14.6
29 13-14 ds	B	7.2-11.0
30 Ganglion, dorsal root	E	8.0
31 Hypothalamus	B	10.4
32 Kidney	M	15.8[5]
33 Kidney	N	38.0
34 Kidney	O	23.2
35 Kidney	L	23.1[6]
36 Kidney	I	34.0
37 Kidney	K	26.0
38 Kidney cortex	D^1	38.2
39 Liver	M	7.2[7]
40 Liver	O	8.1
41 Liver	L	9.0
42 Liver	I	10.7
43 Liver	J	26.0
44 Liver	D^1	17.2
45 Liver, fetus	A	8.7-11.9
46 3-21 da	B	13.2
47 Adult	E	9.8-10.2
48 Adult	B	6.5-11.6
49 Lung	D^1	9.6
50 Adult	C	7.9
51 Adult	B	4.4-7.8
52 Embryo	A	10.0
53 Lymph nodes	B	4.4
54 Mammary, term. of preg.	B	1.3
55 Mammary, 15-22 da lactation	B	10.0
56 2 da after weaning	B	5.5
57 Medulla, 5 da	B	3.4
58 50 da	B	9.0
59 Adult	B	2.5-4.9
60 Mucosa, colon	B	3.4-14.6
61 Duodenal	B	8.8
62 Gastric	B	7.2
63 Ileum	B	16.7
64 Jejunal	B	12.4
65 Muscle, diaphragm	C[8]	4.1-5.9
66 Diaphragm	A	5.9
67 Heart	B	3.8-10.4
68 Skeletal	B	2.3-3.1
69 Smooth, gastric	B	3.5
70 Smooth, intest.	B	6.3
71 Smooth, intest.	C	7.1
72 Pancreas	B	5.7
73 Pancreas	C	3.7
74 Pancreas	B	5.2
75 Pituitary, anterior	B	5.9
76 Posterior	B	6.6
77 Young	A	12.0
78 Placenta	F	3.5
79 20 da	E	7.3
80 Prostate	B	7.3
81 Retina	B	22.0-32.1
82 Salivary gland	B	11.6-16.6
83 Skin, newborn	B	3.5
84 10-36 da	B	4.9-3.6
85 79 da, adult	B	1.8-1.2
86 Sperm	A	7.7
87 Spleen	D^1	12.7
88 Spleen	B	7.2-12.9
89 Spleen	A	13.0
90 Testis	B	7.2-14.3
91 Testis	A	11.0
92 Thymus	B	5.5-5.8
93 Thyroid	B	12.5-13.5
94 Uterus	B	7.6
95 Uterus	E	3.7
96 Castrate	E	5.2
97 Castrate, plus estrogen	E	7.9
Mouse		
98 Adrenal	A	6.0
99 Brain cortex	D^1	32.9
100 Cerebral cortex	E	11.0
101 Embryo	B	10.4
102 Kidney cortex	D^1	46.1
103 Liver	B	8.8-13.8
104 Liver	E	18.7
105 Liver	D^1	23.1
106 Lung	B	7.3-8.0
107 Lung	D^1	12.0
108 Ovary	A	9.0
109 Placenta, 0.4mg	A	7.5
110 10.9-13.7 mg	A	6.4
111 Pituitary	A	8.0
112 Skin, newborn	B	6.1
113 Spleen	D^1	16.9
Guinea Pig		
114 Adrenal	A	6.0
115 Brain cortex	D^1	27.3
116 Cerebral cortex	C	6.9
117 Cerebral cortex	C,L^9	11.7
118 Epithelium[10]	B	6.1
119 Of cestrus	B	2.8
120 Kidney cortex	D^1	31.8
121 Liver	D^1	13.0
122 Liver	E	8.1
123 Liver	E	5.0
124 Fatty	E	7.4
125 Lung	B	6.1
126 Lung	C	7.4
127 Lung	D^1	8.5
128 Muscle, smooth[9]	B	1.7
129 Of castrate	B	1.4
130 Pancreas	C	2.7
131 Salivary gland	C	5.0
132 Skin	B	3.0
133 Sperm	B	0.0
134 Sperm	A	10.4
135 Spleen	D^1	11.6
136 Spleen	C	8.13
Rabbit		
137 Brain cortex	D^1	28.2
138 Cerebral cortex	B	7.3-10.4
139 Embryo	B	8.5
140 Ganglion, celiac	A	4.0
141 Kidney cortex	D^1	34.5
142 Liver	D^1	11.6
143 Liver	B	4.2-7.7
144 Lung	D^1	8.0
145 Lung	B	6.7
146 Marrow, erythroid cells	In A	9.0
147 Myeloid cells	A	6.0
148 Mucosa, colon	B	A 11.1
149 Uterine	A	6.1
150 Muscle, diaphragm	B	2.4
151 Smooth, intest.	B	2.6
152 Pancreas	B	4.6
153 Placenta, fetal side	A	5.3
154 Uterine side	A	5.4
155 Sperm, ejaculated	D^1	4.4
156 Spleen	D^1	14.2
157 Testis	B	7.7
158 Thyroid	B	A 11.7
Cat		
159 Brain cortex	D^1	26.9
Cat (concluded)		
160 Cerebral cortex	B	8.5-12.2
161 Kidney cortex	D^1	22.7
162 Liver	D^1	13.2
163 Lung	D^1	3.9
164 Lung	B	3.9
165 Medulla	B	3.5
166 Muscle, heart	B	2.5
167 Smooth, intest.	B	1.4
168 Pancreas	B	5.8
169 Salivary, acetyl-choline stimulation	B	13.6
170 Exerine + AcCH	B	22.7
171 Resting	B	10.3
172 Spinal cord	B	3.3
173 Spleen	D^1	8.4
Dog		
174 Brain cortex	D^1	21.2
175 Caudate nucleus	C,L^9	1.36
176 Cerebellum	C,L^9	1.07
177 Cerebral cortex	C,L^9	1.16
178 Cerebral cortex	B	6.7
179 Heart	M	2.6
180 Heart	L	2.7
181 Heart	I	4.6
182 Heart	K	6.3
183 Kidney cortex	D^1	27.0
184 Liver	B	9.0
185 Liver	D^1	11.7
186 Lung	D^1	4.9
187 Medulla	C,L^9	0.69
188 Muscle, skeletal	D^1	1.2
189 Muscle, skeletal	L	1.3
190 Muscle, skeletal	I	1.7
191 Diaphragm, young	B	1.9
192 Diaphragm, juvenile	B	4.2
193 Heart	B	2.6
194 Pancreas	B	3.2
195 Retina	B	20.8
196 Salivary	B	10.6
197 Spinal cord	C,L^9	0.5
198 Spleen	D^1	6.6
199 Thalamus	C,L^9	1.01
200 Thyroid	A	9.1
201 Thyroid	B	2.0
202 Midbrain	C,L^9	0.92
Horse		
203 Brain cortex	D^1	15.7
204 Kidney cortex	D^1	21.5
205 Liver	D^1	5.4
206 Liver	B	2.1
207 Lung	D^1	4.4
208 Spleen	D^1	4.2
Cattle		
209 Brain cortex	D^1	17.2
210 Kidney cortex	D^1	23.5
Cattle (concluded)		
211 Liver	D^1	8.2
212 Cow	B,	2.6
213 Lung	D^1	4.3
214 Retina, ox	B	10.7
215 Sperm	D	6.6
216 Sperm	F	11.2
217 Sperm	G	12.8
218 Sperm, epididymal	D,	2.6
219 Spleen	D^1	4.4
220 Thyroid, calf	B	2.6
Swine		
Cerebral cortex		
221 29-60 da fetus	E	5.5
222 99 da fetus	E	6.5
223 Birth to adult	E	8.5
224 Retina	B	17.7
225 Thyroid, hog	B	2.1
Sheep		
226 Brain cortex	D^1	19.7
227 Kidney cortex	D^1	27.5
228 Liver	B	2.5
229 Liver	D^1	8.5
230 Lung	D^1	5.4
231 Sperm, ejaculated	D	9.0
232 Spleen	D^1	6.9
233 Trigeminal, nerve	E	0.5
234 Ganglion	E	0.3
Chick		
235 Allantois	B	22.3
236 Embryo, 0.1-1.2 g	A	15.9-21.4
237 4.7 g	A	8.1
238 5-6 da	E	10-12
239 12 da	E	9.9
240 19 da	E	7.7
241 Brain	A	25.0
242 Heart, 4 da	A	30
243 Heart, 6-7 da	A	14.9
244 Liver, 6 da	A	7.5
245 Liver, 12 da	B	8.5
246 Liver, 20 da	B	1.5
Fowl		
247 Liver, hen	A	14.5
248 Sperm, ejaculated	D	2.8
Pigeon		
249 Cerebral cortex	C,L^9	14.6
250 Lung	B	3.6
251 Muscle, skeletal	C	2.1
252 Pancreas	C	8.7
Frog		
253 Hippocampus	E	2.4
254 Muscle, skel., rest.	B	.18-.24
255 Elect. stim.	E	.79-4.24
256 Smooth, intest.	B	.28
257 Nerve, sciatic	E	0.3
258 Retina	B	3.5
259 Spinal cord	B	2.3

[1] Medium essentially Ca-free Ringer phosphate, but containing pyruvate (or lactate), fumarate, glutamate and glucose. [2] Value of 5.4 also reported. [3] Value of 8.1 also reported. [4] Value of 9.8 also reported. [5] Value of 17.8 also reported. [6] Value of 19.4 also reported. [7] Value of 8.8 also reported. [8] Range shows a decrease with age. [9] Phosphate saline medium containing glucose. [10] From seminal vesicles.

Data unless otherwise specified are for adults in resting or basal state. Rate values for protozoa are cubic millimeters oxygen per milliou celle per hour, and for metazoa, cubic millimeters oxygen per gram fresh weight per hour (= cubic centimeters per kilogram per hour). Rates for poikilothermic vertebrates and invertebrates were measured at the indicated ambient temperatures.

	Organism	Rate
	Mammalia	
1	Man, maximum work	4000
2	Man, resting	200
3	Anteater, spiny	1100
4	Armadillo	201
5	Bat, brown, big	800
6	Bat, brown, little	1500
7	Bear, polar, cub	700
8	Cat, Australian, native	560
9	Cow	390
10	Dog	580
11	Dormouse, awake	852
12	Dormouse, hibernating	15
13	Elephant, Indian, 37 yr, ♀	155
14	Fox, arctic, white	505
15	Guinea pig	1250
16	Hamster	1050
17	Hamster, golden, awake	2900
18	Hamster, golden, hibernating	70
19	Horse	130
20	Lemming	1700
21	Manatee, Florida sea cow	120
22	Marmoset	1040
23	Monkey, night	510
24	Mouse, house, basal	1530
25	Mouse, house, resting	3500
26	Opossum, Australian	700
27	Platypus, duckbilled	460
28	Porpoise	360
29	Rabbit	460-850
30	Raccoon	395
31	Rat	2000
32	Rat, kangaroo	950
33	Seal	540
34	Sheep	340
35	Shrew, Mooterey	7200
36	Shrew, long-tailed	13,700
37	Shrew, short-tailed	5200
38	Shrew, Sonoma, ♂	6100
39	Shrew, Sonoma, ♀	5500
40	Sloth, two-toed	216
41	Sloth, three-toed	168
42	Squirrel, arctic, ground	600
43	Squirrel, flying	2000
44	Swine	220
45	Weasel	5000
46	Woodchuck, awake	262
47	Woodchuck, hibernating	14
	Aves	
48	Bunting, snow	3350
49	Canary	2900
50	Dove	950
51	Duck	800
52	Fowl, hen	630
53	Goose	547-592
54	Gull, arctic	1640
55	Hawk, night	1750
56	Hummingbird, day	13
57	Manakin	4620
58	Pigeon	710
59	Sparrow	2100
	Reptilia	
60	Alligator lucius, 25ºC	64
61	A. mississippiensis, 22ºC	8. 9
62	Coluber natrix, 20ºC	92-150
63	Constrictor constrictor, 16ºC	4. 9
64	C. constrictor, 22ºC	10
65	C. constrictor, 30ºC	24
66	Crotalus atrox, 16ºC	6. 8
67	C. atrox, 22ºC	16. 4
68	C. atrox, 30ºC	35. 5
69	Drymarchoo corais couperi, 16ºC	10. 1
70	D. corais couperi, 22ºC	20
71	D. corais couperi, 30ºC	47
72	Iguana tuberculata, 22ºC	22. 2
73	I. tuberculata, 30ºC	52
74	Lacerta agilis, 20ºC	1980
75	Malaclemys centrata, 24ºC	35
76	Python reticulatum, 22ºC	12. 2
77	Storeria dekayi, ♂, 20ºC	266
78	S. dekayi, ♀, 20ºC	183
79	Testudo vicina, 22ºC	22

	Organism	Rate
	Amphibia	
80	Molge vulgaris, 20ºC	123
81	Rana esculenta, winter, 20ºC	85
82	R. esculenta, summer, 20ºC	437
83	R. fusca, winter, 20ºC	100
84	R. fusca, summer, 20ºC	210
85	R. temporaria, winter, 19ºC	85
86	R. temporaria, summer, 19ºC	554
	Pisces	
87	Anguilla vulgaris, 25ºC	128
88	Arapaima gigas, 25ºC	9
89	Cobitis fossilis, 20ºC	51
90	Crenichthys baileyi, 37ºC	546
91	Cyprinus tinca, 20ºC	104
92	Esox lucius, 18ºC	102
93	Heliasis chromis, 20ºC	162
94	Lepidosiren paradoxa, 20ºC	42
95	Salmo trutta, 12ºC	226
96	Scomber scombrus, 20ºC	726
97	Serranus scriba, 20ºC	151
98	Sphoerondes maculatus, 20ºC	62
99	Steootomus chrysops, 20ºC	174
100	Tautoga onitis, 20ºC	62
101	Tautogolabus adspersus, 21ºC	120
	Cephalochordata and Tunicata	
102	Amphioxus lanceolatus, 16ºC	135
103	A. lanceolatus, 20ºC	45
104	Ascidia mentula, 25ºC	4. 8
105	Salpa pinnata, 16ºC	8
106	S. pinnata, 20ºC	12
107	S. tilesii, 16ºC	2. 0
108	S. tilesii, 20ºC	2. 8
	Arthropoda	
109	Apis mellifera, resting, 20ºC	17, 466
110	A. mellifera, true flight, 20ºC	87, 000
111	Asellus aquaticus, 17ºC	348
112	Astacus leptodactylus, 20ºC	70
113	Callianax subterranea, 15ºC	930
114	Carcinus maenus, 15ºC	625
115	Cryptocercus punctulatus, 5ºC	28. 5
116	Culex sp, 20ºC	575
117	Dronia vulgaris, 17ºC	3000
118	Drosophila americana, resting, 20ºC	1560
119	D. america, true flight, 20ºC	21, 800
120	Emerita talpoida, 20ºC	112
121	Eriphia spinifrons, 15ºC	1828
122	Formica sp, 20ºC	532
123	Geotrupes sp, 21ºC	447
124	Homarus americanus, 15ºC	507
125	Ilia nucleus, 15ºC	253
126	Limnophilus vittatus, 10ºC	500
127	Lucilia sericata[1], 20ºC	95, 600
128	Maja verrucosa, 15ºC	1460
129	Melanotus communis, 27ºC	2400
130	Melolootha sp, 20ºC	724-960
131	Musca sp, 20ºC	3200-5112
132	Oocyde albicans, 26ºC	139
133	Paguristia maculata, 15ºC	1600
134	Palaemon squilla, 19ºC	128
135	Palinurus vulgaris, 15ºC	12, 874
136	Pandalina brevirostris, 15ºC	20
137	Passalus cornutus, 20ºC	30
138	Peripaneta orientalis, 20ºC	277
139	Pilumnus hirtellus, 15ºC	160
140	Pugettia producta, 15ºC	100
141	Sicyonia sculpa, 15ºC	443
142	Spirontocaris cranchi, 15ºC	6
143	Talorchestia megalophaima, 17ºC	180
144	Venessa sp, resting, 20ºC	600
145	Venessa sp, true flight, 20ºC	100, 000
146	Zootermopsis angusticollis, 20ºC	400
	Annelida	
147	Arenicola sp, 12ºC	30
148	Chaetopterus pergamentaceus 15ºC	8
149	Glycera siphonostoma, 25ºC	15
150	Lumbricus communis, 21. 5ºC	206
151	L. herculeus, 10ºC	45
152	L. terrestris, 20. 5ºC	138

	Organism	Rate
	Annelida (concluded)	
153	Nereis virens, 15ºC	26
154	Sipunculus nudus, 16ºC	50
155	Tubifex sp, 15ºC	200
	Mollusca	
156	Aplysia limacina, 15ºC	30
157	Eledone moschata, 16ºC	181
158	Helix pomatia, 20ºC	94
159	Limax agrestis, 20ºC	350
160	Mytilus edulis, 14ºC	13
161	M. galloprovincialis, 25ºC	18
162	Octopus vulgaris, 16ºC	47-87
163	Pleurobranchea meckeli, 25ºC	36
164	Pterotrachea coronata, 16ºC	7. 8
165	Sepia officinalis, 15ºC	320
166	Tethys leporina, 16ºC	12
	Echinodermata	
167	Asterias rubens, 15ºC	30
168	Holothuria impatiens, 25ºC	17
169	Ophioderma longicauda, 25ºC	8-32
170	Strongylocentrotus lividus, 25ºC	15
	Nemathelminthes	
171	Ascaridia galli, 37ºC	525
172	Ascaris lumbricoides, large, 37ºC	72
173	A. lumbricoides, small, 37ºC	1.56
174	A. lumbricoides, ♂, 37ºC	112
175	A. lumbricoides, ♀, 37ºC	61
176	Heterakis spumosa, 38ºC	880
177	Litomosoides carinii, 37. 5ºC	800
178	Nematodirus sp, 37ºC	1070
179	Neoaplectana glaseri, 30ºC	2600
180	Nippostrongylus muris, 37ºC	1430
181	Oesterlagia circumcincta, 38ºC	1480
182	Setaria equinum, 38ºC	250
183	Strongylus equinus, 38ºC	511
184	Sybnacia obvelata, 38ºC	1010
	Platyhelminthes	
185	Dendrocoelum lacteum, 2. 5ºC	4. 4
186	D. lacteum, 25ºC	26. 3
187	Diphyllobothrium latum[2], 37ºC	243
188	Fasciola hepatica, 37. 10ºC	330
189	Paramphistomum cervi, 38ºC	3
190	Planaria torva, 2. 5ºC	18. 9
191	P. torva, 25ºC	75. 8
192	Thaenophorus nodulosus[3], 22ºC	418
	Ctenophora	
193	Beroe ovata, 10ºC	5
194	Cestus veneris, 16ºC	2. 6
195	C. veneris, 25ºC	25
	Coelenterata	
196	Anemonia sulcata, 18ºC	13. 4
197	Aurelia aurita, 13ºC	3. 4
198	Carmarina hastata, 16ºC	6
199	Rhizostoma pulmo, 16ºC	7. 2
	Porifera	
200	Suberites massa, 22. 4ºC	0. 0241
	Protozoa	
201	Amoeba chaos chaos, 20ºC	7050
202	A. chaos chaos, 25ºC	9010
203	A. chaos chaos, 30ºC	13, 244
204	Astasis klebsii, young, 25. 2ºC	3. 8
205	Chilomonas paramecium, 25ºC	16. 4
206	Leishmania brasiliensis, 32ºC	0. 32
207	Leptomonas ctenocephali, 28ºC	0. 37
208	Paramecium aurelia[4], 20ºC	354
209	P. aurelia[5], 25ºC	616
210	P. aurelia[4], 35ºC	1512
211	P. caudatum[4], 20ºC	2110
212	P. caudatum[4], 25ºC	3860
213	P. multimicronucleatum[5], 25ºC	1021
214	Plasmodium cathemerium, 38ºC	0. 25
215	P. knowlesi, 38ºC	0. 34
216	Strigomonas fasciculata, 28ºC	0. 37
217	Tetrahymena geleii[6], 26. 8ºC	632. 5
218	Trichomonas foetus, 28ºC	2. 15
219	Trypanosoma congolense, 37ºC	1. 53
220	T. cruzi, 37ºC	1. 24
221	T. gambiense, 37ºC	1. 70
222	T. lewisi, old, 37ºC	0. 51
223	T. rhodesiense, 37ºC	1. 94

/1/ True flight. /2/ Proglottids. /3/ Scolbila. /4/ No substrate. /5/ Bacteria present. /6/ Substrate present.

243. RESPIRATION RATES: PLANTS

Part 1: FUNGI

Values for rates of gaseous exchange are μl/mg dry weight/hour, except as otherwise specified. Data for aerobic CO_2 production are enclosed in parentheses; those for anaerobic CO_2 production in brackets. Values not enclosed are O_2 consumption.

	Species	Material	Temp °C	Substrate	Specifications	$[Q_{CO_2}]$ or Q_{O_2}	RQ
				Myxomycetes			
1	Physarum polycephalum	Plasmodium	22		Endogenous	(1.0) 2.4[1]	0.75-0.85
				Phycomycetes			
2	Allomyces arbuscula	Mycelial mat	20	Carbohydrate	Starved	0.8	
3	A. moniliformis	Mycelial mat		Carbohydrate	Starved	1.0	
4	Cystopus candidus	Mycelial mat		Natural	Host, host + fungus		0.93, 0.95
5	Leptomitus lacteus	Pellets	20		Endogenous; at 0, 4, 8 days	20, 15, 10	0.98
6	Mucor guillermondi	Mycelial mat	25		Endogenous; mycelial phase	5.7-10 [7.1]	
7		Mycelial mat	25	Carbohydrate	+ Glucose; mycelial phase	5.6-21.4 [18.82]	
8		Mycelial mat	25		Endogenous; yeast phase	7.1-8.6	
9		Mycelial mat	25	Carbohydrate	+ Glucose; yeast phase	7.8-39 [31-142]	
10	M. stolonifer	Mycelial mat	20, 30	Carbohydrate			1.53, 1.72
11	Phycomyces blakesleeanus	Mycelial mat	20	Carbohydrate	At 1.5, 3.5, 7 days	(27, 13, 3)	
12	Rhizopus sp.	Mycelial mat	28	Carbohydrate		(4.7)	
				Ascomycetes			
13	Ashbya gossypii	Mycelium[2]	30		Endogenous; at 1, 2, 3 days	19, 11, 8	
14		Mycelium[2]	30	Carbohydrate	+ Glucose; at 1, 2, 3 days	32, 20, 12	
15		Mycelium[2]	30	Carbohydrate	+ Sucrose; at 1, 2, 3 days	30, 17, 13	
16		Mycelium[2]	30	Carbohydrate	+ Lactose; at 1, 2, 3 days	0, 0, 0	
17		Mycelium[2]	30	Complex	+ Pyruvate; at 1, 2, 3 days	8, 3, 0	
18		Mycelium[2]	30	Complex	+ Ethanol; at 1, 2, 3 days	12, 8, 3	
19	Erysiphe graminis tritici	Growing culture	22	Natural	Host, host + fungus	1.7, 6.0[3]	
20	Melanospora destruens	Mycelial mat	30	Carbohydrate	+ Glucose	6	
21	Neurospora crassa	Mycelial mat	30	Organic comp'd	Endogenous	11-38 [0-5]	
22	N. tetrasperma	Sexual spores	25		Endogenous; dormant	0.2-0.6 [0.03]	
23		Sexual spores	25		Endogenous; germinating	9-22 [1-2]	
24	Saccharomyces cerevisiae R	Cell suspension		Carbohydrate	No stored reserves	83-109 [278-299]	
25		Cell suspension			Fat as reserves	76 [322]	
26		Cell suspension			Glycogen as reserves	0 [116]	
27	S. cerevisiae U	Cell suspension		Carbohydrate	No stored reserves	10-137 [276-284]	
28		Cell suspension			Fat as reserves	125 [261]	
29		Cell suspension			Glycogen as reserves	47 [83]	
30	Sclerotinia sp.	Pellets	23-25	Carbohydrate			1.15
31	Zygosaccharomyces acidifaciens	Mycelium[2]	28		Endogenous; at 24, 48, 72 hr	16, 7, 7	
32		Mycelium[2]	28	Carbohydrate	+ Glucose; at 24, 48, 72 hr	60, 35, 35	
				Basidiomycetes			
33	Boletus luridus	Sporophore	17		Endogenous	(1.5)	
34	Bovista tunicata	Sporophore			Endogenous	(1.8-1.1) [8.7-5.6]	
35	Coprinus comatus	Sporophore	17		Endogenous	(2.7)	
36	Exidia glandulosa						0.7
37	Lactarius serifluus	Sporophore	17		Endogenous	(2.7)	
38	Polyporus squamosus	Sporophore	17		Endogenous	(1.0)	
39	Polystictus versicolor	Mycelial mat	17.5	Complex	At 2, 21, 100% O_2	3, 8.5, 10.4[3]	
40		Mycelial mat	29.5	Complex	At 2, 21, 100% O_2	7.4, 4.2, 17.2[3]	
41	Psalliota campestris	Growing culture	25			1.9-2.9	
42	Puccinia pruni	Growing culture		Natural	Host, host + fungus		1.06, 0.82
43	Ustilago sphaerogena	Conidia			Endogenous	75	
44		Conidia		Carbohydrate	+ Sugars	150-375	
				Fungi Imperfecti			
45	Aspergillus clavatus	Mycelial mat	15-25	Carbohydrate		12.4	
46		Mycelial mat		Complex		44	
47	A. flavus	Mycelial mat	30	Carbohydrate	At 4-6 days	6-7	
48	A. niger	Mycelial mat	19, 35	Carbohydrate	+ Glucose		0.98, 1.30
49		Mycelial mat	18, 35	Carbohydrate	+ Sucrose		0.91, 1.22
50		Mycelial mat	36	Carbohydrate	+ Glycerol		0.82-0.86
51		Mycelial mat	35	Carbohydrate	+ Mannitol		1.20
52	Blastomyces dermatitidis	Cell suspension	37		Endogenous; at pH 2, 6, 8	0.5, 12, 11[4]	
53		Cell suspension	37	Carbohydrate	+ Glucose; at pH 2, 6, 8	1, 12, 12[4]	
54	Candida albicans	Cell suspension	30		Endogenous	5	
55		Cell suspension	30	Carbohydrate	+ Glucose	40	
56	Fusarium avenaceum	Pellets	23-25	Natural			5.46
57	F. dianthi	Pellets	23-25	Natural			1.85
58	F. trichothecioides	Mycelium[2]	30		Endogenous; at 1-4 hrs[5]	31-11	
59		Mycelium[2]	30	Carbohydrate	+ Glucose; at 1-4 hr[5]	64-56	
60	Helminthosporium gramineum	Pellets	23-25		Endogenous		1.31
61	H. inaequalis	Pellets	23-25		Endogenous		1.16
62	Memnoniella echinata	Conidia	30		Endogenous; at pH 4, 6, 8	1.0, 1.5, 1.3	
63		Conidia		Carbohydrate	+ Glucose; at pH 4, 6, 8	2.6, 3.1, 2.7	
64		Conidia		Carbohydrate	+ Lactose; at pH 4, 6, 8	0.7, 1.3, 1.2	
65	Myrothecium verrucaria	Conidia	30	Carbohydrate	+ Glucose; at pH 4, 6, 8	1.9, 25, 30	
66		Conidia		Carbohydrate	Endogenous; at pH 4, 6, 8	2.9, 2.6, 5.6	
67		Pellets			Starved, sucrose grown	42	
68	Penicillium chrysogenum	Pellets	23-25	Carbohydrate	3 strains		1.10-1.27
69	P. digitatum	Pellets	23-25	Carbohydrate	4 strains		1.39-1.63
70	P. notatum	Mycelial mat	23-25	Carbohydrate	At 4-8-11 days	46-198-152[4]	
71	Torulopsis utilis	Cell suspension	30		Glycine	3.7[1]	0.86
72		Cell suspension	30		Urea	3.5[1]	1.15
73		Cell suspension	30		α-Alanine	5.2[1]	0.89
74		Cell suspension	30		β-Alanine	6.2[1]	1.16

/1/ μl/mg wet wt/hr. /2/ Homogenized. /3/ μl/sq cm area/hr. /4/ μl/10 μl tissue volume/hr. /5/ 1-day old.

Part II: BACTERIA

Data are applicable to bacterial suspensions in the presence of glucose. Values are ml/mg dry weight/hr.

	Species	Temp °C	Culture Age hr	Q_{O_2}
1	Azotobacter chroococcum	22	36	2,000-10,000
2	Aerobacter aerogenes	36, 30	17, 48	47, 50
3	Bacillus cereus (short)	30?	18	42-86
4	B. cereus (filamentous)	30?	18	3-49
5	B. subtilis	37	6-8	170
6	Escherichia coli	40, 32	20	200, 272
7	Lactobacillus bulgaricus	37, 45	8	34, 55
8	Leuconostoc citrovorum	38	16	8
9	Micrococcus luteus	35	30-34	15
10	M. flavus	35	30-34	8
11	M. varianticus	35	30-34	14
12	M. cinnebarecus	35	30-34	32
13	M. freundereichii	35	30-34	20
14	Mycobacterium phlei	38	84	28
15	M. smegmatis	38	84	23
16	M. tetrveris	38	84	15
17	M. sp Karlinski	38	84	22
18	M. ranae	38	84	32
19	M. lepraus kedrowsky	38	84	8
20	M. butyricum	38	84	13
21	M. tuberculosis hominis	38	252	4
22	M. tuberculosis avian	37	84	1
23	Pneumococcus, Type I	37	18	27
24	Pseudomonas fluorescens	26	20	58
25	Streptococcus faecalis, B33A	38	18	106
26	S. faecalis, 10C1	37	15	57-80
27	S. faecalis, Lancefield D	37	12-15	7
28	S. thermophilus, C3	37, 50	8	4, 5
29	S. thermophilus, MC	37, 50	8	9, 10

Part III: ALGAE

Values for rates of gaseous exchange are µl/100 mg dry weight/hr, except as otherwise specified. Data for O_2 consumption are enclosed in brackets; those for CO_2 production are not enclosed.

	Species	Temp °C	CO_2 or $[Q_{O_2}]$	RQ
	Cyanophyta (Blue Green)			
1	Anabaena sp	25	4.4	0.90
2	Nostoc commune	19	0.16	0.40
	Chlorophyta (Green)			
3	Chara vulgaris	18	1.5[1]	
4	Chlorella ellipsoidea	25	[147]	
5	C. pyrenoidea	20	89	0.89
6	C. vulgaris	20	[475-192][2]	
7	Cladophora rupestris	20	[33]	
8	Coelastrum proboscideum	20	[170]	
9	Enteromorpha compressa	20	27	3.6
10	E. linza	19	66	0.62
11	Haematococcus pluvialis	20	[180]	
12	Nitella flexilis	18	1.6	
13	Scenedesmus obliquus	25	[50]	
14	Spirogyra majuscula	10.4	[0.5][1]	
15	S. varians	10.4	[0.6][1]	
16	Ulva lactuca	20	13-16	2.4-6.1
17	Valonia utricularis	20	8.4	1.5-5.7
	Phaeophyta (Brown)			
18	Ascophyllum nodosum	20	1.7[1]	0.80
19	Chorda tomentosa	9	[74]	
20	Cutleria multifida	20	7.2-17	0.5-2.1
21	Cystoseira abrotanifolia	20	4.5-10	1.2-3.7
22	C. amentacea	20	17	3.9
23	C. barbata	20	13-17	2.1-4.0
24	Desmarestia aculeata	14	[24]	
25	D. viridis	14	[14][1]	
26	Dictyota dichotoma	20	9.4-9.2	0.98-1.04
27	Ectocarpus siliculosus	12	[41][1]	
28	Fucus serratus	18	18[1]	0.54
29	F. vesiculosus	17	11	0.60
30	Laminaria digitata	17	[2][1]	
31	Taonia atomaria	20	6.7-20	0.9-3.1
	Rhodophyta (Red)			
32	Cerasmium rubrum	17	45	0.89
33	Chondrus crispus	14	[18]	
34	C. crispus	20	[28]	
35	Ciadostephus spongiosus	20	[39]	
36	Cryptonemia lomation	20	7.5-9.9	2.4-3.8
37	Delesseria sista	20	[41]	
38	Furcellaria fastigata	14	[7]	
39	Gelidium corneum	20	13	3.26
40	Gracilaria compressa	20	9	1.4
41	Laurencia papillosa	20	18	4.88
42	Phyllophora nervosa	20	4.6	1.56
43	Plocamium coccineum	14	[21]	
44	Polyides lumbricoides	14	[5]	
45	Polysiphonia urceolata	12	[10][1]	
46	P. violacea	11	107	1.02
47	Porphyra laciniata	17	[39]	

/1 µl/100 mg fresh wt/hr. /2/µl/10⁵ cells/hr.

Part IV: LICHENS

Values are µl/100 mg dry weight/hr.

	Species	30°C	10°C	0°C
1	Alectoria nigricans	33	14	8
2	Cetraria chrysantha	19	9	3.9
3	C. glauca	61	31	10
4	C. islandica	48	19	8
5	Cladonia schaiaderi	13	7.5	3.1
6	C. sylvatica	24	6.8	2.9
7	Cornicularia divergens	40	11	5
8	Lobaria linita	72	22	10
9	L. scrobiculata	50	29	12
10	Parmelia nigrociliata	25	13	4
11	Peltigera aphthosa	90	33	17
12	Ramalina aludens	13	3.3	2.2
13	Solorina croces	43	24	10
14	Sticta lacinata	28	11	7
15	S. weigelii	40	14	6.7
16	Thamnolia vermicularis	28	14	4.2
17	Umbilicaria cinereorufescens	30	9.8	4.1
18	U. proboscidea	18	6.5	3.5

	Species	Temp °C	Q_{O_2}	RQ
19	Cladonia rangiferina	50	10	0.80
20	Evernia prunastri	50	40	0.78
21		60	30	0.88
22	Orthotrichum affine	55	17	0.70
23	Pertusaria communis			0.84
24	Physica aipolia			0.73
25	C. ciliaris	45	18	0.80
26	Ramalina farinacea	50	25	0.77

Part V: LIVERWORTS, MOSSES

Values are µl/100 mg dry weight/hr, except as otherwise specified. Data for O_2 consumption are enclosed in brackets; those for aerobic CO_2 are not enclosed.

	Species	Temp °C	CO_2 or $[Q_{O_2}]$
	Liverwort (Hepaticae)		
1	Chilioscyphus fragilis	25	[60-100]
2	Marchantia polymorpha	20	0.6[1]
3	Riccia fluitans	25	[250-300]
	Mosses (Musci)		
4	Fontinalis antipyretica	25	[70-140]
5	Hylocomium parietinum	30	92
6		20	46
7		0	15
8	H. proliferum	30	92
9		20	46
10		0	15
11	H. squarrosum	30	100
12		20	61
13		0	15
14	Hypnum cupressiforme	18.5	[2-30]
15	H. fluitans	18	0.83[2]
16	Polytrichum juniperium, shoot[3]	18	1.2-0.7[2]
17	Sphagnum girgensohnii	30	130
18		20	71
19		5	20

/1/ µl/sq cm/hr. /2/µl/100 mg fresh wt/hr. /3/ Data show changes during growth, development, maturation.

Part VI: HORSETAILS, FERNS

Values for gaseous exchange are µl/100 mg wet weight/hr. Data for O_2 consumption are enclosed in brackets; those for aerobic CO_2 production are not enclosed.

	Species	Material	Temp °C	CO_2 or $[Q_{O_2}]$	RQ
	Horsetail (Equisetinae)				
1	Equisetum maximum	Shoot	20	6	0.78
2		Fruiting shoot	20	100	0.83
3		Stem	RT	9.6	0.80
4		Branchlet	RT	19	0.69
	Ferns (Filicinese)				
5	Asplenum adiantum nigrum	Leaf	20	13	0.86
6		Leaf with sori	20	17	1.01
7		Leaf blade	RT	13.4	0.80
8		Petiole	RT	8.3	0.80
9	Bryopteris austriaca	Leaf	48	122	
10		Leaf	30	36	
11		Leaf	10	25	
12	Eupteris aquilina	Leaf	48	168	
13		Leaf	30	46	
14		Leaf	10	15	
15	Polypodium virginiana	Leaf	20	10	0.92
16		Leaf with sori	20	19	1.06
17	Pteris aquilina	Leaf	22	19	0.84
18		Leaf with sori	22	35	1.01
19	Scolopendrium scoloen-drium	Leaf	30	[31]	
20		Leaf	22	[17.5]	
21		Leaf	13	[9.9]	
22		Leaf	3	[2.2]	

Values for rates of gaseous exchange are $\mu l/100$ mg wet weight/hour, except as otherwise specified. Data for anaerobic CO_2 production are enclosed in parentheses; those for O_2 consumption in brackets. Values not enclosed are aerobic CO_2 production.

Part VII: SEEDS AND PARTS

	Species	Material[1]	Temp °C	Q_{CO_2}	RQ
1	Apple (Pyrus malus	Resting	19	2.8[2]	0.86
2	Alfalfa (Medicago sativa)	Resting	18	41	1.08
3		Germinating	18	91	0.86
4	Barley (Hordeum vulgare)	Resting		8.7	
5		Embryo		63	
6		Endosperm		3.6	
7	Bean (Phaseolus coccineus)	Resting	28		1.75
8	Broadbean (Vicia faba)	Resting	28		0.99
9	Broom (Cytisus laburnum)	Resting	28		1.16
10	Buckwheat (Fagopyrum esculentum)	Germinating	25	41-306	0.8-1.0
11	Castor bean (Ricinus communis)	Resting	28		1.03
		Endosperm	30	54	0.38
13	Cherry (Prunus cerasus)	Moist	25	5.6	0.87
14	Coconut (Cocos nucifera)	Moist	30	100-200	
15		Endosperm	30	0	
16		Hypocotyl	30	50	
17	Corn (Zea mays)	Resting		1.7	
18		Embryo		22.6	
19		Endosperm		0.36	
	Cotton (Gossypium herbaceum)				
20	Coker	Resting	26	0.1-1.5	0.92-1.05
21	Delfos	Resting	26	0.03-6.0	0.96-1.12
22	Flax (Linum usitatissimum)	Resting	17	21.8	0.91
23		Germinating	18	117	0.55
24	Hemp (Cannabis sativa)	Resting	18	9.0	0.82
25	Lamb's-quarters (Chenopodium album)	Moist	25	8.9	0.93
26	Peach (Prunus persica)	Moist	25	3.9	0.68
27	Plum (P. domestica)	Resting	28		0.80
28	Plum, blue gage (P. domestica)	Moist	25	5.6	0.70
29	Plum, Burbank (P. domestica)	Moist	25	4.3	0.91
30	Pumpkin (Cucurbita pepo)	Germinating	25	10-117	0.94-0.62
31	Radish (Raphanus sativus)	Resting	20	6.0	0.86
32		Germinating	20	60	0.58
33	Red cedar (Juniperus virginiana)	Resting	25	0.05	0.76
		Germinating	25	6.6-25	0.84-0.97
35	Rice (Oryza sativa)	Resting		0.03^2	1.15
36		Moist		5.5^2	1.96
37		Germinating		9.7^2	1.98
38		Seedling		1.1^2	1.00
39	Rye (Secale cereale)	Resting	38	0.002-0.1	
40	Smartweed (Polygonum scandens)	Moist	6		0.90
41		Moist	30		0.92
42	Sorghum (Sorghum vulgare)	Resting	37.8	$0.01-0.3^2$	
43	Sorrel (Rumex crispus)	Moist	25	7.8	1.16
44	Sunflower (Helianthus annuus	Resting	28		1.05
45	Walnut (Juglans regia)	Resting	28		0.52
46	Watermelon (Citrullus vulgaris)	Resting	28		0.90
47	Wheat (Triticum aestivum)	Resting	65		0.3^2
48		Resting	55		0.7^2
49		Resting	35		0.03^2
50		Resting	4		0.005^2

/1/ Condition of seeds: resting=dormant, air-dry; moist=with imbibed water. /2/ $\mu l/100$ mg dry wt/hr.

Part VIII: STEMS

	Species	Temp °C	Q_{CO_2} or $[Q_{O_2}]$	RQ
1	Apple, Jonathan (Pyrus malus)[2]	6	2.3-4.6	
2	Apple, McIntosh (P. malus)[2]	6	1.7-3.8	
3	Asparagus (Asparagus officinalis)[3]	24	35-13.2	1.04-0.95
4		10	9.7-1.6	1.03-0.86
5		0.5	3.0-2.0	0.98-0.95
6	Borage (Borago officinalis)	RT	6.1	0.81
7	Broadbean (Vicia faba)	RT	6.2 (5.6)	
8	Broom (Spartium junceum)	RT	16	0.80
9	Charlock (Raphanus raphanistrum)	RT	10.5	0.87
10	Cinquefoil (Potentilla reptans)	RT	11.0	0.83
11	Clematis (Clematis cirrhosa)	RT	12.4 (7.5)	
12	Cotton (Gossypium herbaceum)[4]	18	148-425	
13	Elder (Sambucus nigra)	RT	9.8 (7.7)	
14	Nettle (Urtica membranacea)	RT	8.8	0.88
15	Oak (Quercus coccifera)	21	31-11	0.89-0.83
16	Oxalis (Oxalis corniculata)[4]	RT	15.4	0.97
17	Pea (Pisum sativum)	RT	14.9	0.86
18	Smartweed (Polygonum persicaria)	RT	6.9	0.82
19	Sorrel (Rumex lunaria)	RT	10 (8.1)	
20	Sorrel (R. pulcher)	RT	11.8	0.85
21	Sugar cane (Saccharum officinarum)[4]	28	27-45	
22	Vetch (Vicia sativa)	RT	14.9	0.86

/1/ RT=room temperature. /2/ Tissue precooled. /3/ Material observed under conditions of storage or starvation. /4/ Data applicable to conditions of growth, development, maturation. /5/ $\mu l/100$ mg dry wt/hr.

Part IX: FLOWERS AND PARTS

	Species	Material	Temp °C	Q_{CO_2} or $[Q_{O_2}]$	RQ
1	Agave (Agave attenuata)[1]	Stamen	15	24-21	0.78-0.74
2		Pistil	14	34-13-11	0.92-0.69
3	Aloe (Aloe arborescens)[1]	Stamen	17	36-21-11	
4		Pistil	17	26-23-25	0.93-0.94
5	Arum (Arum italicum)	Spadix	18	[2800]	
6	Begonia (Begonia rex)	Sepal	20	39	
7		Petal	20	37	
8		Stamen	20	43	
9		Pistil	20	31	
10	Cacalia (Cacalia verbescifolia)	Flower	18	34(15)	
11	Canna (Canna indica)	Petal	22	27	0.79
12		Stamen	22	65	0.72
13		Pistil	22	45	0.78
14	Columbine (Aquilegia vulgaris)	Ovule	20	[190][2]	
15	Cucumber (Cucumus sativus)[1]	Pistil	22	48-43-29	
16	Cyclamen (Cyclamen persicum)	Flower	28		1.03
17	Dahlia (Dahlia variabilis)	Petal	28		0.94
18	Delphinium (Delphinium sinense)	Flower	28		0.94
19	Eel-grass (Vallisneria spiralis)	Flower	20	[30][2]	
20	Elder (Sambuscus nigra)	Flower	28		0.95
21	Fleabane (Erigeron annua)	Flower	18	[40] (23)	
22	Gladiolus (Gladiolus gandavensis)	Petal	24	15	0.72
23		Stamen	24	27	0.77
24		Pistil	24	71	0.90
25	Lilac (Syringa vulgaris)	Flower	20	40	
26	Jasmine (Jasmunum nudiflorum)	Flower	28		0.01
27	Lily (Lilium elegans)	Pollen	25	[610] (240)[2]	
28	Lily (L. hansoni)	Pollen	25	[340] (260)[2]	
29	Lily (L. philippinensis)	Pollen	25	[1140] (980)[2]	1.04
30	Marsh marigold (Caltha palustris)	Ovule	20	[360][2]	
31	Mullein (Verbascum thapsus)	Stamen	23	76	0.83
		Pistil	23	82	0.92
33	Peony (Paeonia albiflora)	Pollen	25	[700] (170)[2]	
34	Pine (Pinus densiflora)	Pollen	25	[160] (150)[2]	
35	Poppy (Papaver orientale)	Pollen	25	[520] (0)[2]	
	Poppy (P. rhoeas)	Sepal	21	39	
37		Petal	21	37	
38		Stamen	21	104	
39		Pistil	21	69	
40	Primrose (Primula obconica)	Flower	28		0.96
41	Sweetpea (Lathyrus odoratus)	Ovule	20	[420][2]	
42		Ovary	20	[300][2]	
43		Filament	20	[160][2]	
44	Tulip (Tulipa gennerlana)	Flower	28		0.95

/1/ Data show changes during growth, development, maturation. /2/ $\mu l/$ per 100 mg dry wt/hr.

Part X: STORAGE ORGANS

	Species	Material	Temp °C	Q_{CO_2} or $[Q_{O_2}]$	RQ
1	Arrow-head (Sagittaria latifolia)	Rhizome	25	4.1 (3.2)	
2	Artichoke (Cynara scolymus)[1]	Tuber	25	1.4-0.8 (0.5)	
3	Beet (Beta vulgaris)	Root	15.5	0.8	
4	Bur-reed (Sparganium eurycarpum	Rhizome	25	[2.3] (1.6)	
5	Carrot (Daucus carota)[1]	Root	14	3.3-1.5	1.10-1.18
6			10	1.5-0.5	1.08-1.01
7			0.5	0.4-0.2	0.92-1.16
8	Cattail (Typhe latifolia)	Rhizome	25	2.4(2.1)	
9	Dahlia (Dahlia variabilis)	Root	25		0.99
10	Gladiolus (Gladiolus sp)	Corm	23	8.5^2	
11	Milkweed (Asclepias incarnata)	Rhizome	25	3.7(4.3)	
12	Onion (Allium cepa)	Bulb	21	0.7-1	
13			10	0.4-0.5	
14			0	0.1-0.2	
15	Oxalis (Oxalis cernua)	Rhizome	RT	5	1.18
16	Potato (Solanum tuberosus)[1]	Tuber	24	0.6-0.3	1.02-0.75
17			10	0.2-0.15	0.86-0.99
18			0.5	0.07-0.15	0.45-0.66
19	Sedge (Scirpus validus)	Rhizome	25	2.8(3.4)	
20	Sweetflag (Acorus calamus)	Rhizome	25	3.7(3.7)	
21	Sweetpotato (Ipomoea batatus) Puerto Rico	Root	35	6.2	
22			25	4.0	
23			15	1.9	
24	Triumph	Root	35	5.6	
25			25	3.2	
26			15	1.4	
27	Turnip (Brassica rapa)	Root	15.5	1.6	
28			4.5	0.1	
29			0	0.02	
30	Waterlily (Nuphar advenum)	Rhizome	25	3.0(2.6)	

/1/ Material observed under conditions of storage or starvation. /2/ $\mu l/100$ mg dry wt/hr.

243. RESPIRATION RATES: PLANTS (Concluded)

Values for rates of gaseous exchange are µl/100 mg wet weight/hour, except as otherwise specified. Data for anaerobic CO_2 production are enclosed in parentheses; those for O_2 consumption in brackets. Values not enclosed are aerobic CO_2 production.

Part XI: LEAVES

	Species	Temp/°C	Q_{CO_2} or [Q_{O_2}]	RQ
1	Almond (Prunus amygdalus)	14	29	1.00
2	Bamboo (Bambusa nana)[2]	22.5	22-8.5	
3	Barley (Hordeum vulgare)	23	26.6(11.6)	0.85
4	Barley (IL vulgare), etiolated	23	21.6(11.2)	0.83
5	Bean (Phaseolus vulgaris)	26	26-57	
6	Beech (Fagus sylvatica)	21	34	
7	Beet (Beta vulgaris)	27	23	
8	Begonia (Begonia rex)	20	30	
9	Broadbean (Vicia faba), blade	RT	11.1(5.1)	
10	Broadbean (V. faba), petiole	RT	4.1(4.3)	
11	Broom (Spartium junceum), blade	RT	17	0.71
12	Buttercup (Ranunculus glacialis)	20	28	
13		10	19	
14		0	5.1	
15	Catalpa (Catalpa bignonioides aurea)	14	18	
16	Catalpa (C. bignonioides koehnei)	14	25	
17	Cattail (Typha latifolia)[2]	22.5	26-15-19	
18	Charlock (Raphanus raphanistrum), blade	RT	13.3	0.73
19	Charlock (R. raphanistrum), petiole	RT	6.2	0.86
20	Cinquefoil (Potentilla reptana), blade	RT	31.9(12.5)	0.67
21	Cinquefoil (P. reptans), petiole	RT	10.7(5.6)	0.83
22	Coffee (Coffea arabica)	20	1.5[3]	0.86
23	Corn (Zea maya)	26	68(17.1)	0.99
24	Corn (Z. mays), etiolated	26	54(18.1)	0.97
25	Dandelion (Taraxacum officinale)	19	46	0.95
26	Duckweed (Lemna minor)	25	300[4]	
27	Elm (Ulmus montana)	16	24	
28	Elm (U. montana aurea)	16	22	
29	Elm (U. montana atropurpurea)	16	23	
30	Eucalyptus (Eucalyptus globulus)	19	8.5	0.80
31	Gladiolus (Gladiolus gandavensis)	24	18	0.64
32	Horsechestnut (Aesculus hippocastanum)	12	49	
33	Horsechestnut, white (A. hippocastanum)	12	26	
34	Ivy (Hedera helix)	32	40	1.00
35		18	18	1.00
36	Lettuce (Lactuca sativa)[2]	24	3.3-2.6	1.12-1.02
37		10	1.3-0.7	1.09-1.00
38		0.5	0.95-0.4	0.88-0.98
39	Lime (Citrus aurantium)	20	3.0[3]	
40	Mallow (Malva parviflora), blade	RT	32	0.84
41	Mallow (M. sylvestris), blade	RT	12.3	0.71
42	Maple (Acer pseudoplatanus)	10	33	
43	Maple (A. pseudo. atropurpureum)	16	23	
44	Maple (A. pseudo. cupreum)	16	24	
45	Maple (A. pseudo. luteo-virescens)	10	28	
46	Mullein (Verbascum thapsus)	26	38	0.84
47	Nettle (Urtica membranaceae), blade	RT	10.8	0.69
48	Nightshade (Solanum nigrum), blade[2]	16	34-10	0.78-0.67
49	Olive (Olea europaea)[2]	22	24-13	0.78-0.75
50	Optunia (Optunia versicolor)	65	6	
51		55	21	
52		45	33	
53		35	15	0.70
54	Pine (Pinus canariensis)	29	42	0.90
55	Pine (P. maritima)	36	5	0.87
56		20	12	0.84
57		0	2	0.83
58	Potato (Solanum tuberosum)	48	137	
59		30	41	
60	Purslane (Atriplex hortensis)	18	44	
61	Reed (Phragmites communis)[2]	22.5	31-12	
62	Rye (Secale cerale)	25	44	
63		15	26	
64	Sorrel (Rumex acetosa), blade	RT	21.6	0.76
65	Sorrel (R. pulcher), blade	RT	14.7	0.76
66	Spinach (Spinacia oleracea)[2]	24	16.2-12.8	0.94-0.83
67		10	4.2-2.0	0.90-0.86
68		0.5	1.5-5.8	0.85-0.73
69	Squill (Scilla peruviana)	20	4	0.78
70	Sunflower (Helianthus annuus)	42	24.3[3]	
71		31	16.6[3]	
72		20	5.8[3]	
73	Tea (Thea sinensis), sections	36	16.4(8.6)	
74	Tomato (Lycopersicon esculentum)	28	260[4]	
75	Rutgers	28	210[4]	
76	Vetch (Vicia sativa), blade	RT	30.1	0.75
77	Vetch (V. sativa), petiole	RT	16.7	0.88
78	Vetch (V. sativa), tendril	RT	27.7	0.90
79	Wheat (Triticum aestivum)	25	40(10.6)	0.97
80	Wheat (T. aestivum), etiolated	25	38(11.7)	0.98
81	Yew (Taxus baccata)	46	55	0.89
82		16	6	0.86
83	Yucca (Yucca gloriosa)[2]	22.5	13.6-5.1	

Part XII: FRUITS

	Species	Temp/°C	Q_{CO_2} or [Q_{O_2}]	RQ
1	Apple (Pyrus malus)	20	1.7-0.4-0.4	
2	Delicious[1]	27	7.2-4.5	0.45-0.92
3	Malden blush[2]	25	4.2-20	
4		0	1.4-2.4	
5	Winesap[2]	25	1.9-0.9	
6		0	1.8-0.6	
7	Apricot (Prunus armeniaca)[2]	18	2.8-4.1	
8		4	1.1-1.0	
9	Avocado (Persea gratissima)[2]	5	1	
10		25	7-15	
11	Banana (Musa paradisca sapientum)	31	3.1	
12		20	1.8	
13		12.5	0.9	
14		0	0.4	
15	Barberry (Berberis vulgaris)	25		1.20
16	Bean (Phaseolus vulgaris)[2]	24	16.4-6.6	1.1-1.0
17		0.5	6.95-0.6	0.94-0.96
18	Bryony (Bryonia dioica)[1]	25	64-8.5	
19	Cherry (Prunus avium)[1]	20	68-2	
20	Corn (Zea mays)[1]	30	21-18(12-9)	
21	Cranberry (Vaccinium)[1]	24	32-14	
22	Cucumber (Cucumis sativus)[2]	24	2.3-0.8	1.01-0.91
23		10	1.0-0.5	1.01-1.10
24		0.5	0.2-0.7	0.97-0.88
25	Elder (Sambucus nigra)	18	12(11)	
26	Grape (Vitis vinifera)	28		1.6
27	Grapefruit (Citrus grandis)	38	2.5	1.2
28		21	1.0	1.1
29		10	0.6	1.4
30		0	0.1	1.2
31	Guava (Psidium guajava)[2]	30	20-3.6	
32	Hawthorn (Crataegus punctata	28		1.26
33	Ivy (Hedera helix)[1]	20	13.5-10.9	
34	Lemon (Citrus limonia)	38	4.1	1.4
35		10	0.5	1.1
36		0	0.15	1.2
37	Lilac (Syringa vulgaris)[1]	25	42-8.5	
38	Oak (Quercus alba)	30	14.9[3]	0.71
39		10	4.8[3]	0.30
40		2.5	2.7[3]	0.16
41	Oak (Q. rubra)	30	6.4[3]	0.46
42		10	3[3]	0.13
43		2.5	1.6[3]	0.08
44	Okra (Hibiacus esculentus)[2]	30	306-104	
45	Orange (Citrus nobilis)	28		1.07
46	Orange (C. sinensis) Washington navel	21	2.0	1.1
47		10	0.8	1.1
48		0	0.2	1.2
49	Valencia	38		1.7
50		21	1.8	1.0
51		0	0.2	1.1
52	Papaya (Carica papaya)	15.6	0.83	
53		10	0.46	
54		4.4	0.24	
55	Pea (Pisum sativum)[2]	24	20-12	1.32-1.06
56		10	7.9-3.1	1.13-1.00
57		0.5	2.2-1.4	1.00-0.96
58	Peach (Prunus persica)	18	1.4-2.0[2]	
59		4	0.4-0.3[2]	
60		25	7-5[1]	
61		25	8-2[2]	
62	Pear (Pyrus communis)	18	6.3-1.1.2[1]	
63		18	1-0.9-2.2[2]	
64	Pepper (Capsicum frutescens)[2]	24	4.0-1.4	1.12-0.88
65		10	2.0-0.6	1.27-0.88
66		0.5	0.4-0.3	0.96-0.96
67	Persimmon, Hachiya (Diospyros kaki	20-27	1.8	1.2
68	Persimmon, Fuyu (D. kaki)	20-27	1.4	1.1
69	Pigeon pea (Kajanus indicus)[1]	21	30-0	
70	Pimento (Pimenta officinalis)	30	40[3]	
71	Plum (Prunus domestica)	18	8.7(5.6)	
72	Poppy (Papaver somniferum)	20	38	1.5
73	Rye (Secale cerealе)[1]	28	[240-12][3]	
74	Smartweed (Polygonum scandens)	30		0.87
75	Snowberry (Symphoricarpos ramosus)	17	33	
76	Strawberry, misionary (Fragaria sp)	20	3.3-5.1	0.84-0.91
77	Strawberry (F. vesca)	28		1.27
78	Tobacco (Nicotiana tabacum)	28		0.94
79	Tomato (Lycopersicon esculentum)	24	2.5-1.6[2]	1.11-1.13
80		10	0.8-0.6[2]	1.39-1.06
81		0.5	0.4-0.2[2]	1.11-1.02
82		28	2.6-2.5[1]	1.8-1.4
83	Wheat (Triticum aestivum)[1]	28	[340-8][3]	

/1/ RT = room temperature. /2/ Material observed under conditions of storage or starvation. /3/ µl/sq cm/hr /4/ µl/100 mg dry wt/hr.

/1/ Data show changes during growth, development, maturation. /2/ Material observed under conditions of storage or starvation. /3/ µl/100 mg dry wt/hr.

244. RESPIRATORY MEDIA: CHARACTERISTICS

Water and nitrogen are the two major ecological variations of respiratory media available to organisms. These media are the solvents, mechanically inspired by the actively ventilated respiratory organ, through which occurs the exchange of oxygen and carbon dioxide. Values identified with an asterisk (*) are averages of many determinations but vary widely with conditions of measurement.

	Variable	Water		Atmosphere (N_2)	
		Ocean	Fresh	Sea Level	Altitude[1]
1	Temperature, °C	-2.0 to 30.0	2.0-32.0	0.7-15.7	-28.1 to +15.1
2	Pressure, total, mm Hg	760-760,000	760-20,000	760	347.5-360.2
3	Density, g/L	1027* (20°C)	1000* (4°C)	1.223-1.290	0.649-0.659
	Concentration				
4	H_2O, vol %	100.00	100.00	1.00[2]	1.00[2]
5	N_2, vol %	1.03* (15°C)	1.33* (15°C)	78.03 (STP)	78.03 (STP)
6	CO_2, vol %	0.02* (15°C)	0.03* (15°C)	0.03 (STP)	0.03 (STP)
7	O_2, vol %	0.58* (15°C)	0.72* (15°C)	20.99 (STP)	20.99 (STP)
8	Salte, vol %	3.46*	0.18*		
9	pH	7.5-8.4	3.2-10.6		
10	Inert gases, vol %	Trace	Trace	0.95 (STP)	0.95 (STP)
	Partial Pressure (Tension)				
11	H_2O (mm Hg)	12.79 (15°C)	6.10 (4°C)	6.40[3] (15°C)	0.72[3] (-15°C)
12	N_2 (mm Hg)	593.02 (STP)	593.02 (STP)	593.02 (STP)	281.06[4] (STP)
13	CO_2 (mm Hg)	0.23* (STP)	0.23* (STP)	0.23 (STP)	0.11[4] (STP)
14	O_2 (mm Hg)	159.52* (STP)	159.52* (STP)	159.52 (STP)	75.61[4] (STP)
15	Inert gases	7.46 (STP)	7.46 (STP)	7.46 (STP)	3.42[4] (STP)
16	Total pressure	760.00	760.00	760.00	360.20
	Diffusion Coefficient m/min/sq cm x cm (760 mm Hg, 20°C)				
17	H_2O				
18	N_2		0.000018[5] (0.53)[6]		
19	CO_2		0.000785[5] (23.1)[6]		
20	O_2		0.000034[5] (1.0)[6]	11.0	

/1/ 6000 meters. /2/ Varies, but never absent and always of biological significance. /3/ Calculated for 50% relative humidity. /4/ Calculated from Lines 5, 6, 7, 10 and 16. /5/ Calculated from measured value for O_2 (Line 20) and relative coefficients (Lines 18, 19). Values in parentheses are relative coefficients with O_2 as unity.

245. RESPIRATORY MOLECULES: CHARACTERISTICS

Values, unless otherwise indicated, are for standard conditions (STP) of temperature (0°C) and pressure (760 mm Hg).

	Type	Weight (O=16)	Diameter[1] cm x 10^{-8}	Density g/L	Mean Free Path cm x 10^{-6} (750 mm Hg)	Collision Frequency (20^0C)	Average Velocity cm x 100/sec	Water Solubility STP	Water Solubility 20^0C	Vol % (40°C)
1	N_2	28.02	3.15-3.53	1.251	8.50	5070	454	2.35	1.54	1.18
2	H_2O	18.02	3.0-5.0	0.005-0.030[2]			566			
3	CO_2	44.01	3.34-3.40	1.977	5.56	6120	362	171.3	87.8	53.0
4	O_2	32.00	2.92-2.98	1.429	9.05	4430	425	4.89	3.10	2.31

/1/ Range indicates variability with method of measurement (e.g. viscosity, heat conductivity). /2/ Water vapor in saturated air, i.e., in equilibrium with water, at 0°C and 30°C.

246. RESPIRATORY EXCHANGE CHARACTERISTICS: MAN

Part I: VENTILATION

	Gas	Inspired Air		Alveolar Air		Expired Air	
		Composition vol %	Partial Pressure mm Hg^2	Composition vol %[1,3]	Partial Pressure mm Hg[3,4]	Composition vol %[1]	Partial Pressure mm Hg[4]
		A	B	C	D	E	F	G
1	H_2O	0.00	5.7	00.0	47	00.0	47
2	N_2	79.02	596.0	80.4	573	79.2	565
3	O_2	20.95	158.0	14.0	100	16.3	116
4	CO_2	0.03	0.3	5.6	40	4.5	32

/1/ Dry air, partial pressure in mm Hg, = B/100 x 760 mm Hg (Dalton's Law). /2/ Ambient air (slight variations exist), in vol %, = 100 C/760 (Dalton's Law). /3/ "Alveolar" air, actually last part of expired samples. /4/ Physiological air, normal temperature (37°C) and standard pressure (760 mm Hg).

Part II: TRANSPORT

Values in parentheses are ranges.

	Gas	Arterial		Capillary		Tissue Fluid		Venous	
		vol %	mm Hg	vol %	mm Hg	vol %	mm Hg	vol %	mm Hg
1	H_2O	83(81-86)	47	83(81-86)	47	83(81-86)	47	83(81-86	47
2	N_2	0.975	573	0.975	573	0.975	573	0.975	573
3	O_2	19.6(17.3-22.3)	94	1-22.3[1]	1-94[1]	0.185[1]	30[1]	12.9(11.0-16.1)[2]	40
4	CO_2	48.2(44.6-50.4)	40	44.6-57.7[1]	40-50	3.046[1]	50[1]	54.8(51.0-57.7)[2]	46

/1/ Variable, depending on blood flow, tissue activity and relation of sample to capillary length or field. /2/ Internal jugular.

247. RESPIRATORY EXCHANGE CHARACTERISTICS: VERTEBRATES

Volume per cent values are for dry air.

	Animal	Inspired Air vol %		Alveolar Air vol %		Expired Air vol %		RQ
		O_2	CO_2	O_2	CO_2	O_2	CO_2	CO_2/O_2
1	Man (Homo sapiens)	20.99	0.03	14.00	5.60	16.30	4.50	0.850
2	Dog (Canis familiaris)			13.66	5.68	16.30	3.46	0.780
3	Albino rat (Rattus norvegicus)							0.894 (0.754-1.072)
4	Horse (Equus caballus)							0.960
5	Guillemot (Cepphus grylle)					15.05	4.83	
6	Chicken (Gallus domesticus)					13.50	6.50	0.764[1] (0.71-0.96)[2]
7	Turtle (28°C) (Malaclemys centrata)			16.46	4.69			0.71[3]
8	Frog (20°C), cutaneous (Rana esculenta)							1.92
9	Frog (20°C), pulmonary (R. esculenta)							0.32
10	Puffer fish (20°C)	0.31		0.31		0.149		

/1/ Average for 5 days including day of last feeding. /2/ Range for 1-5 hr and 4 days after feeding. /3/ Data for painted turtle (Chrysemys marginata) included in calculation.

248. LUNG VENTILATION: VERTEBRATES

Values, unless otherwise noted, are averages of means for the resting state. Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

	Species	Respiration Frequency breath/min	Tidal Volume[1] ml	Minute Volume[2] L
	Man (Homo sapiens)			
1	Premature	33	12.4(8.4-17.3)	0.41(0.28-0.58)
2	Newborn, asleep	43(24-116)	16.7(10.0-27)	0.72(0.43-1.41)
3	Adult ♂	11.7(10.1-13.1)[3]	750(757-895)[4]	7.4(5.8-10.3)[5]
4	♀	11.7(10.4-13.0)[6]	339(285-393)[7]	4.5(4.0-7.0)[8]
5	Cat (Felis catus)	26	12.4	0.32
6	Cow (Bos taurus)	31(27-40)	2850(2200-3800)	86(59-104)
7	Dog	18(11-38)	320(251-432)	5.2(3.3-7.4)
8	Goat	19.0	310	5.7
9	Guinea pig (Cavia cobaya)	90(69-104)	1.8(1.0-3.9)	0.16(0.09-0.38)
10	Hamster (Mesocricetus auratus)	74(53-127)	0.83(0.42-1.2)	0.054(0.025-0.083)
11	Horse (Equus caballus)[9]	11.9(10.6-13.6)	9000(8520-9680)	107
12	Manatee, Florida (Trichechus latirostris)	7.0(6.0-8.0)	(5000-9000)	45(35-60)
13	Marmot (Marmota marmota)	8.0[10]	22.0[11]	0.1712
14	Monkey (Macaca mulatta)	40(31-52)	21(9.8-21)	0.86(0.31-1.41)
15	Mouse (Mus musculus)	163(84-230)	0.15(0.09-0.23)	0.023(0.011-0.036)
16	Porpoise (Tursiops truncatus)	1.1(0.9-1.3)	9,000(8,000-10,000)	9.7(9.0-10.4)
17	Rabbit (Lepus cuniculus)	51(38-60)	21(19.3-24.6)	1.07(0.80-1.14)
18	Rat (Rattus norvegicus)		1.5(1.4-1.6)	0.100(0.075-0.130)
19	Rat, cotton (Sigmodon hispidus)	94(75-115)	0.35(0.24-0.70)	0.034(0.023-0.071)
20	Sloth (Choloepus hoffmani)	13.0		0.84(0.80-1.0)
21	Sloth (Bradypus griseus)	(4.5-8.0)		0.49(0.33-0.73)
22	Turtle (Malaclemys centrata)	3.7	14.0	0.05

/1/ Air inspired per breath. /2/ Respiration frequency x tidal volume. /3/ Resting. Light work, 17.1(15.7-18.2); heavy work, 21.2(18.6-23.3). /4/ Resting. Light work, 1670(1510-1770); heavy work, 2030(1900-2110). /5/ Resting. Light work, 29(27-31); heavy work, 60(50-90). /6/ Resting. Light work, 19; heavy work, 30(25-33). /7/ Resting. Light work, 860(836-885); heavy work, 880(690-1270). /8/ Resting. Light work, 16.3(15.9-16.8); heavy work, 24.5(17.3-32.0). /9/ Percheron, gelding. /10/ Hibernating, 0.68. /11/ Hibernating, 13(11.3-15.0). /12/ Hibernating, 0.009.

249. PULMONARY VALUES, EQUATIONS, DEFINITIONS: MAN

Part I: LUNG AIR VOLUME, RECUMBENT

Values are from smoothed curves plotted from mean values, and are for the following conditions: 37°C, ambient pressure, saturated with water vapor. Ranges in parentheses are from smoothed curves of ranges, and are estimate "d" of the 95% range (cf Introduction).

	Age yr	Total Lung Capacity[1] L	Vital Capacity[2] L
1	Six ♂	1.6(1.3-2.1)	1.2(0.9-1.7)
2	♀	1.6(1.3-2.1)[3]	1.2(0.9-1.7)[3]
3	Ten ♂	2.5(2.2-3.1)	1.9(1.6-2.4)
4	♀	2.5(2.2-3.1)[3]	1.9(1.6-2.4)[3]
5	Fourteen ♂	4.6(3.5-6.1)	3.7(3.0-4.7)
6	♀	3.6(2.8-4.3)[3]	2.7(2.2-3.5)[3]
7	Eighteen ♂	5.9(4.3-8.0)	4.6(4.0-5.8)
8	♀	4.1(3.1-5.3)[3]	3.0(2.4-4.2)[3]
9	Twenty ♂	6.3(4.3-8.5)	4.9(4.0-6.0)
10	♀	4.2(3.1-5.3)[3]	3.0(2.4-4.4)[3]
11	Twenty-five ♂	6.4(4.3-9.0)	4.9(3.3-6.0)
12	♀	4.2(3.1-5.4)	3.0(2.2-4.2)[3]
13	Thirty-five ♂	6.1(4.3-8.5)	4.5(2.3-6.0)
14	♀	4.3(3.0-5.6)	3.0(2.0-3.8)
15	Forty-five ♂	5.9(4.3-8.0)	4.3(2.8-5.1)
16	♀	4.3(2.9-5.7)	2.9(1.8-3.7)
17	Fifty-five ♂	5.8(4.3-8.0)	4.1(2.6-5.5)
18	♀	4.2(2.8-5.7)	2.7(1.6-3.5)
19	Sixty-five ♂	5.6(4.3-7.0)	3.7(2.5-5.0)
20	♀	3.9(2.8-5.5)[3]	2.3(1.4-3.4)[3]
21	Seventy-five ♂	5.2(4.3-7.0)	3.3(2.5-4.5)
22	♀	3.9(2.8-5.0)[3]	2.2(1.4-3.5)[3]

/1/ Total volume of air contained in lungs after deepest possible inspiration. Total lung capacity minus vital capacity equals residual capacity or residual air. /2/ Volume of air expired in deepest possible expiration following deepest possible inspiration. /3/ Values are estimates; a sex difference may exist.

Part II: INTRAPULMONIC (INTRA-ORAL) PRESSURE

Values are for males only. Mean-lung volumes are given as per cent of vital capacity. Ranges in parentheses are estimate "b" of the 95% range (cf Introduction).

	Volume %	mm Hg
	Maximum Expiratory Pressure	
1	9.7	142(4.7-68)
2	25.0	52(10.9-94)
3	44	70(30-109)
4	60	90(47-133)
5	75	93(58-128)
6	83	107(74-144)
7	100	120(86-165)
	Maximum Inspiratory Pressure	
8	3.9	85(47-125)[1]
9	21.7	75(46-103)[1]
10	35	63(26-101)[1]
11	56	57(26-88)[1]
12	76	45(16.8-73)[1]
13	91	24(2.2-49)[1]
	Relaxation Pressure	
14	0	-1.9(-32-+6.6)
15	13.9	-8.5(-15.5 to +1.5)
16	31	-1.3(-9.9 to 7.3)
17	51	4.1(-1.9 to 10.1)
18	72	10.5(1.9 to 19.1)
19	87	14.9(0.3 to 29.5)
20	100	20.6(10.2 to 31)

/1/ Negative pressure.

Part III: INTRAPLEURAL PRESSURE

Values are cm H_2O relative to atmospheric pressure.

	Condition	Inspiration	Expiration
1	Adults, at rest	-5 to -10	-3 to -5
2	Deep breathing	-30	
3	Müller's[1]	-50 to -60	
4	Valsalva's[2]		60
5	Normal[3]	-0.7(-0.5 to -1.0)	0.4(0-1.0)
6	Labored[3]	-1.1(-0.5 to -1.5)	2.4(1.0 to 3.0)
7	Normal[4]	-1.3(-1.0 to -1.5)	2.6(1.0 to 3.5)
8	Infants, end of inspiration	-5	
9	End of expiration		0

/1/ Inspiration with glottis closed. /2/ Expiration with glottis closed. /3/ Air pressure at posterior pharynx. /4/ Air pressure at tracheal bifurcation.

Part IV: PREDICTION EQUATIONS

Equations are applicable for the following conditions: 37°C, ambient pressure, saturated with water vapor. MBC=maximum breathing capacity, L/min; SA=body surface area, sq m; V=pulmonary ventilation, L/min; W=weight, kg; VC=vital capacity, L; H=height, cm; A=age, yr.

	Subject	Equation
1	Infants, <1 week, resting	$V = 0.139 + 0.00367\ W^{1}$
2	Males, 10-17 yr	$VC = 0.0562\ H + 0.0097\ AW - 6.27$
3	140-160 cm	$VC = 0.0492\ H - 4.82$
4	160-190 cm	$VC = 0.0799\ H - 9.75$
5	Males, standing	$VC = 0.025\ H^{2}$
6	Females, standing	$VC = 0.020\ H^{2}$
7	Males	$MBC = [86.5 - (0.52\ x\ A)]\ x\ SA^{3}$
8	Females	$MBC = [71.3 - (0.474\ x\ A)]\ x\ SA^{3}$
9	Both sexes	$MBC = H\ x\ (1.24 - 0.0095\ A)^{3}$

/1/ Weight in ounces. /2/ Age correction for vital capacity: 46-55 yr = -4%; 56-65 yr = -8%, 66-75 yr = -16%; over 75 yr = -30%. /3/ Values vary widely with equipment and laboratory methods.

Part V: SUMMARY OF VALUES USED IN EVALUATION OF PULMONARY FUNCTION

	Variable	Average "Normal"[1] Values for Men
1	Maximal breathing capacity (MBC)	100-150 liters/min.
2	Vital capacity (VC)	3500-5000 cc.
3	Residual air	1000-1500 cc.
	Ventilation volume per min/sq m BSA	
4	Rest	2.6-3.8 liters
5	Exercise	8.0-10.5 liters
	Oxygen uptake from air breathed	
6	Rest	4.0-5.0% (40-50 cc/liter).
7	Exercise	5.0-6.0% (50-60 cc/liter).
	Carbon dioxide addition to air breathed	
8	Rest	3.2-4.0% (32-40 cc/liter).
9	Exercise	3.4-4.2% (34-42 cc/liter).
	Arterial blood	
	Carbon dioxide content[2]	
10	Rest	48.5 vol %.
11	Exercise	42.5 vol %.
	Oxygen content[2]	
12	Rest	19.0 vol %.
13	Exercise	19.2 vol %.
	Hemoglobin saturation	
14	Rest	96+ %.
15	Exercise	96+ %.
	Mean resting tensions[3]	
16	Oxygen (pO_2)	95 mm Hg.
17	Carbon dioxide (pCO_2)	40 mm Hg.
18	Dyspnea following mild exercise[4]	60 seconds.

/1/ Pathological findings: pulmonary fibrosis, as in silicosis, tuberculosis, bronchiectasis, sarcoidosis, post-radiation fibrosis, pleurisy, hydrothorax, spondylitis and kyphoscoliosis, causes pulmonary insufficiency; the findings are reduction in lung volumes and maximum breathing capacity, normal spirogram, hyperventilation, low blood carbon dioxide and high arterial pH. In emphysema residual air is increased. Maximum breathing capacity and vital capacity are reduced; arterial oxygen content is low, while carbon dioxide content is elevated. In pulmonary edema arterial anoxia results from disturbance of diffusion of gases across the alveolocapillary membrane. Pulmonary hypertension occurs in emphysema, cardiac failure, mitral stenosis, Ayersa syndrome and polycythemia. /2/ Van Slyke method. /3/ Riley method. /4/ 30 step-ups in one min on stool 20 cm high.

Part VI: STANDARDIZED NOMENCLATURE IN RESPIRATORY PHYSIOLOGY

	Standardized Measurement	Previous Measurement
1	Inspiratory reserve volume	Complemental air. Complementary air. Complemental air minus tidal air. Inspiratory capacity minus tidal volume.
2	Expiratory reserve volume	Supplemental air. Reserve air.
3	Tidal volume	Tidal air.
4	Residual volume	Residual air. Residual capacity.
5	Vital capacity	Vital capacity.

Part VII: STANDARD SYMBOLS IN RESPIRATORY PHYSIOLOGY

	Symbol	Variable[1]
		General
1	V	Gas volume in general. (Pressure, temperature and % saturation with H_2O vapor to be stated.)
2	$\dot{V}$	Gas volume per unit time.
3	P	Gas pressure in general.
4	F	Fractional concentration in dry gas phase.
5	$\dot{Q}$	Quantity flow of blood.
6	C	Concentration in blood phase.
7	F	Respiratory frequency-breaths per unit time.
8	R	Respiratory exchange ratio in general ($vol\ CO_2/vol\ O_2$).
9	D	Diffusing capacity in general (volume per unit time per unit pressure difference).
		Gas Phase
10	I	Inspired gas.
11	E	Expired gas.
12	A	Alveolar gas.
13	T	Tidal gas.
14	D	Dead space gas.
15	B	Barometric.
		Blood Phase
16	b	Blood in general.
17	a	Arterial (exact location to be specified).
18	v	Venous (exact location to be specified).
19	c	Capillary (exact location to be specified).
		Special
20	$\bar{X}$	Dash above any symbol indicates a mean value.
21	$\dot{X}$	Dot above any symbol indicates a time derivative.
22	S	Subscript to denote the steady state.
23	STPD	Standard temperature, pressure, dry. (0°C, 760 mm Hg).
24	BTPS	Body temperature, pressure, saturated with water.
25	ATPD	Ambient temperature, pressure, dry.
26	ATPS	Ambient temperature, pressure, saturated with water.

/1/ Definitions, dimensions and conditions must be specified.

Part VIII: GLOSSARY

TIDAL VOLUME: Volume of air inhaled and exhaled during a single quiet cycle. Wide variability in clinically normal individuals reduces the significance of this determination and complicates its interpretation. INSPIRATORY RESERVE VOLUME: Some investigators consider total volume of air from the beginning of quiet respiration and others from the conclusion of quiet respiration. EXPIRATORY RESERVE VOLUME: Volume of air that can be forcibly expired following a quiet expiration. VITAL CAPACITY: Sum of tidal and inspiratory and expiratory reserve volumes. The volume obtained may be any volume but to be of value should be compared to the "normal" standard tables based on surface area, weight, or standing height. RESIDUAL VOLUME: Air in lungs following a full forced expiration. Included with this volume is the minimal air volume which, although present in the alveoli, cannot be readily measured. TOTAL LUNG CAPACITY: Total volume of air in lungs after full inspiration. FUNCTIONAL RESIDUAL CAPACITY: Air present within lungs at midpoint during a quiet respiration, also classified as midcapacity and subtotal volume. RESTING MINUTE VENTILATION: Total volume of air ventilated in one minute under conditions of rest. It varies widely with individuals but rarely in any one individual. MAXIMUM MINUTE VENTILATION: Maximum volume of air ventilated in one minute in conditions of forced breathing (also known as maximum minute volume). VENTILATORY FACTOR: Quotient of maximum minute ventilation divided by resting minute ventilation, but value is widely variable. Inasmuch as the minute resting ventilation is fixed for an individual, its division into the maximum minute ventilation gives a fairly accurate value for the ventilatory factor. The ventilatory factor may be greatly reduced before appearance of dyspneic symptoms upon exertion.

250. ARTIFICIAL RESPIRATION: MANUAL

Values are mean tidal volumes in cu cm/cycle obtained with manual methods of artificial respiration. They are the results of comparative studies on various types of non-breathing human subjects.

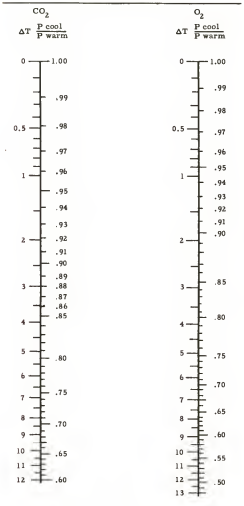
	Method	Warm Corpses[1, 2]	Passive Suspension of Respiration[1, 3]	Apnea				Conscious, Passive[9]	
				Induced by Curare-pentobal-cyclo-propane Mixture[1, 4]	Induced by Anesthesia and Curare Drugs[5, 6]	Intra-cranial Pathology[7, 7]	Intra-cranial Pathology[8]	Male	Female
1	Prone pressure (Schafer)	185	810	485		155	365	466	296
2	Hip Lift (Emerson)	270	883	635			352	871	753
3	Silvester (Arm-lift chest-pressure)	520	1529	1069		285		1087	795
4	Back-pressure arm-lift (Holger Nielsen)	580	1367	1056	474	245	577	1060	748
5	Hip-roll back-pressure	537	1417	967		350		1140	858
6	Hip-lift back-pressure	530	1650	1140	864	405	680		

/1/ University of Illinois investigation. /2/ 26 subjects immediately after death and before onset of rigor mortis. /3/ 10 normal adult male subjects. /4/ 26 normal adult males. /5/ University of Pennsylvania investigation. /6/ 8 pre-operative patients. /7/ 4 patients. /8/ Harvard University investigation; 6 patients. /9/ Springfield College investigation; 15 normal males, 11 normal females.

Part I: TEMPERATURE CHANGES VS. CO_2 AND O_2 TENSIONS

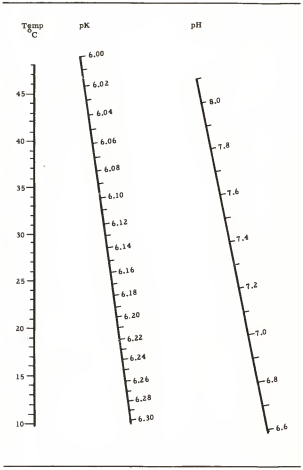
This nomogram illustrates the effect of changes in temperature on CO_2 and O_2 tensions in human or dog blood sealed in an anaerobic environment. The values are applicable to either in vitro or in vivo conditions as, for example, blood sampled into an oil-filled syringe, or blood cooling as it flows through an artery. Nomogram error increases progressively as pH and temperature deviate from standard values of 7.4 and 37°C respectively.

ΔT = temperature change in °C.



Part II: CALCULATION OF SERUM pK

This nomogram allows for calculation of serum pK' for carbonic acid in man and dog when pH and temperature are known. Mean pK' at 37.5°C and pH 7.40 = 6.090.

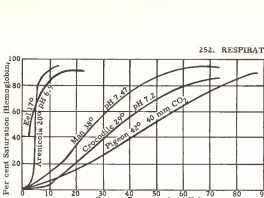


Part III: EFFECT OF BODY TEMPERATURE ON ARTERIAL pH and CO_2 TENSION: DOG

These values illustrate the effect of body temperature on arterial pH and CO_2 tension when tidal volume and rate are constant during cooling in curarized dogs.

	Measurement	At 37°C	At 25°C
1	Oxygen consumption, ml/min	56	18
2	pH	7.28	7.37
3	Plasma CO_2 content, mM/L	19.7	16.5
4	Arterial blood pCO_2, mm Hg	40	23[1]
5	Alveolar pCO_2, mm Hg (end expiratory)	35	19

/1/ The pCO_2 in normal blood (37°, pH 7.4, pCO_2 40) when cooled anaerobically to 25° is, by coincidence, also 23 mm Hg.



The oxygen tension, in mm Hg, at which the respiratory blood pigment (hemoglobin, unless otherwise indicated) is 95 or more per cent saturated, is referred to as the tension of saturation; that at which the pigment is 50% saturated (i.e., when unoxygenated pigment equals oxygenated pigment) is called the tension of half-saturation and indicated as "$t_{\frac{1}{2}}$ sat." The tension of half-saturation for a specific pigment establishes the upper limit of tissue oxygen tension and the lower limit of environmental oxygen for the function of that pigment. When per cent saturation is plotted as ordinate against oxygen pressure as abcissa, the "position" (O_2 pressure required to produce 50% saturation) of the resultant dissociation curve differs from species to species, and varies greatly within the same species with changes in pH and temperature. The figure to the left illustrates dissociation curves for two animals whose blood has a low affinity for oxygen, i.e., a high $t_{\frac{1}{2}}$ sat (pigeon, crocodile), and for two others (arenicola, eel) showing a high affinity and low $t_{\frac{1}{2}}$ sat. In the table below, values in parentheses are extrapolations.

	Species	pCO_2 mm Hg	pH	Temp °C	$t_{\frac{1}{2}}$ sat mm Hg
	Mammalia				
1	Man	142	7.0	37	(39)
2		110	7.1	37	(35.5)
3		84	7.2	37	32.2
4		60	7.3	37	29.2
5		31	7.5	37	23.5
6		22	7.6	37	21.0
7		15	7.7	37	(18.5)
8			0		(1.7)
9			7.4	10	(3.8)
10			7.4	20	8.1
11		(48)	7.4	30	16.2
12		(42)	7.4	40	31.5
13	Cat		7.4	37	38
14		44	7.4	37	35
15	Dog		7.1	37	29.4
16		38	7.4	37.5	28
17		40		38	31.5
18	Fox	40		37.5	37
19	Goat, adult	50		38	28-33
20	Goat, fetal	50		38	25
21	Goat, maternal	50		38	40
22	Horse	50	7.4	37.5	27
23	Llama		7.4	39	20
24		43		38	22
25	Marmot	40		38	23.8
26	Marten	40			38
27	Mink	40			37
28	Mouse	40		38	72
29	Ox		(7.4)	37	29.8
30	Peccary		7.4	37	29
31	Porpoise	46		38	30
32	Rabbit	32	7.4	38.6	31.6
33	Rat		7.4	37	40
34	Rat, kangaroo	40		37	51
35	Rat, white	40		37	56
36	Sea lion	44		38	40
37	Seal	40		38	31
38	Seal, harbor	40		37	28
39	Sheep		(7.4)	37	39
40		40		39	37
41	Swine		(7.4)	37	33.7
42	Vicuna		7.4	39	18
43	Viscacha		7.4	38.6	26
	Aves				
44	Crow	40		42	53
45	Duck, domestic	40		37.5	42
46	Duck, domestic		7.1	37.5	45
47	Fowl	37	7.4	40	51
48		31		38	58
49	Goose		7.1	37.5	45
50		50		42	37.5
51	Huallata		7.35	40	33
52	Ostrich		7.35	40	26
53	Pheasant		7.1	37.5	50
54	Pigeon	40		37.5	35
55		40		42	51
	Reptilia				
56	Alligator	42	7.6	20	28
57	Chuckwalla	37	7.6	20	24
58		(55)		37	62
59	Crocodile	(50)	(7.4)	29	26
60		(45)	(7.4)	37	53
61	Gila monster	36	7.4	20	32
62		(32)	7.4	37	59
63	Turtle	40		25	20
64		27		25	28
65			7.4	25.5	20.3[1, 2]
	Amphibia				
66	Amphiuma		7.38	25.4	15

	Species	pCO_2 mm Hg	pH	Temp °C	$t_{\frac{1}{2}}$ sat mm Hg
	Amphibia (concluded)				
67	Bufo		7.38	25.4	30
68	Cryptobranchus		7.38	25.4	18
69	Desmognathus		7.38	25.4	5
70	"Eel," congo	43		26	30
71	Frog, adult		7.3	25.4	27
72	Frog, tadpole		7.38	25.4	7
73	Triturus		7.38	25.4	7.5
	Pisces				
74	Balara	0		28	8
75	Bom-bom	0		28	11
76	Bowfin	0-1		15	4
77	Carp	1-2		15	5
78		30		18	13
79	Catfish	0-1		15	1.4
80	Cod	<0.3		14	15
81	Eel, salt-water	0.3		17	4
82	Eel, electric	0		28	12
83	Halmars	0		28	8
84	Hasea	0		28	20
85	Mackerel	1		20	16
86		1	8.0	20	17
87	Plaice	0.3		16.5	12
88	Puku	0		28	12
89	Ray		7.38	25	$2\&^2$
90	Ray	1		25	45
91	Ray, sting		7.4	25.5	$13-15^2$
92	Scup		7.38	25	6.4^2
93	Sea robin		7.38	25	2.1^2
94		1	7.7	20	17
95	Shark	1		25	7
96	Shark, sand		7.4	25.5	7.8^2
97	Shark, bonnet nose		7.4	25.5	7^2
98	Salmon, fresh water	1-2		15	21
99	Salmon, brackish	1-2		15	23
100	Skate	1		0.2	11
101		1	7.8	10.4	20
102		1		25	45
103		1		37.5	98
104	Sucker	1-2		15	12
105	Tautog		7.38	25	6^2
106	Toadfish		7.38	25	$3-4.4^2$
107		1	7.7	20	13
108	Trout, brook	1-2		15	17
109	Trout, common	0-3		15	18
110	Trout, rainbow	1-2		15	15
	Invertebrata				
111	Arenicola	0	7.3	17	1.8
112	Busycon[3]	13.5		23	6
113	Cancer[3]	0		23	12
114	Ceriodaphnia	0		17	0.8
115	Chironomus	0		17	0.2-0.6
116	Daphnia	0		17	3.1
117	Gastrophilus	0		39	4.9
118		0		39	0.2^2
119	Helix, summer[3]	0	20	20	12
120	Helix, winter[3]		8.2	20	11
121	Homarus[3]		7.2		90
122	Limulus[3]		7.7		13
123	Loligo[3]	0		23	36
124	Octopus[3]	0.6		25	3
125	Phascolosoma[4]			19	8
126	Planorbis	0		20	7
127		0		17	1.9
128	Sepia[3]	2.3		25	14
129	Sipunculus[4]	0.07-80		19	8
130	Spirographis[5]		7.7	20	27
131	Tubifex	0		17	0.6
132	Urechis[4]	8.6		19	12.3

/1/ Inter-species range 12-28.5. /2/ Dilute hemoglobin solution. /3/ Hemocyanin. /4/ Hemerythrin. /5/ Chlorocruorin.

253. ACID-BASE BALANCE: VERTEBRATES

Part I: GENERAL

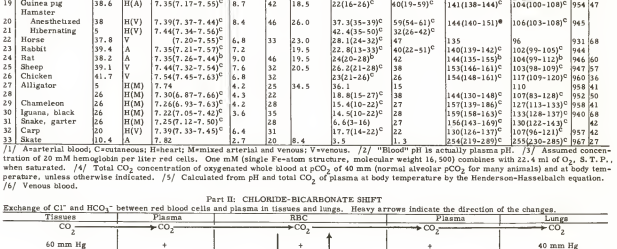
Values in parentheses are ranges and represent estimate "b" or "c" of the 95% range (cf. Introduction).

	Animal	Body Temp °C	Whole Blood: Sample[1]	Whole Blood: pH[2]	Whole Blood: Hemoglobin mM/L[3]	Whole Blood: Cell Volume %	Whole Blood: CO_2 Comb. Power[4] mM/L	Plasma: CO_2 Total mM/L	Plasma: CO_2 Pressure[5] mm Hg	Plasma: Na^+ mEq/L	Plasma: Cl^- mEq/L	Plasma: H_2O g/L	Plasma: Protein g/L
	Man												
1	Birth-10 da	37	C	7.42(7.31-7.53)[b]	10.0			22.7(18-27)[b]	34(27-42)[b]				
2		37	V	7.38(7.30-7.46)[b]	10.3			23.6(20-28)[b]	38				60
3	1 mo-2 yr	37	V	7.38	7.0			24.2(19-29)[b]	38				
4	6-15 yr, ♂♀	37	A	7.40(7.33-7.47)[b]	8.2			25(22-28)[b]	38(29-47)[b]				
5		37	V	7.38(7.32-7.44)[b]	8.2			27(23-30)[b]	43(35-50)[b]				
6	16-50 yr, ♂	37	A	7.39(7.33-7.45)[b]	9.0			27(25-29)[b]	42(36-47)[b]				
7		37	C	7.39(7.33-7.45)[b]	9.4			27	43(35-50)[b]				
8		37	V	7.35(7.27-7.43)[b]	9.0			29(24-34)[b]	49	139(133-143)[c]			73
9	16-50 yr, ♀	37	C	7.41(7.35-7.47)[b]	7.9			26	39(34-44)[b]				
10		37	V	7.37(7.31-7.43)[b]	7.9			27(24-31)[b]	44				
11	Over 50 yr, ♂	37	A	7.41(7.32-7.52)[b]	7.7			25	37(29-45)[b]				
12		37	C	7.39(7.32-7.46)[b]	8.8			27	42(33-50)[b]				
13	Over 50 yr, ♀	37	A	7.42(7.34-7.50)[b]	7.8			25	36(28-54)[b]				
14	Adult, ♂	37	A	7.39(7.33-7.45)[b]	9.0	45	25.7	27(25-29)[b]	42(36-47)[b]	138(132-144)[b]	102(97-108)[b]	940	68
15	Cat	38.6	M	7.35(7.24-7.40)[c]			18.0	20.4(17-24)[b]	36	153(150-156)[b]	120(117-123)[b]	941	
16	Anesthetized	38.6	V	7.28(7.18-7.35)[c]	6.8	40	17.0	21.8(19-25)[c]	45(34-52)[c]		108(105-111)[c]	942	76
17	Cow	38.5	A	[7.35-7.50][b]	7.0	40	21.5					930	83
18	Dog	38.9	A	7.36(7.31-7.42)[c]	9.0	46	18.6	21.4(17-24)[c]	38	147(140-154)[b]	114(108-119)[b]	941	67
19	Guinea pig Hamster	38.6	H(A)	7.35(7.17-7.55)[c]	8.7	42	18.5	22(16-26)[c]	40(19-59)[c]	141(138-144)[c]	104(100-108)[c]	954	47
20	Anesthetized	38	H(V)	7.39(7.37-7.44)[c]	8.4	46	26.0	37.3(35-39)[c]	59(54-61)[c]	144(140-151)[c]	106(103-108)[c]	965	
21	Hibernating	5	H(V)	7.44(7.34-7.56)[c]				42.4(35-50)[c]	32(26-42)[c]				
22	Horse	37.8	V	[7.20-7.55]	6.8	33	23.0	28.1(24-32)[c]	47	135	96	931	68
23	Rabbit	39.4	A	7.35(7.21-7.57)[c]	7.2		19.5	22.8(13-33)[c]	40(22-51)[c]	140(139-142)[c]	102(99-105)[c]	944	
24	Rat	38.2	A	7.35(7.26-7.44)[c]	9.0	46	19.5	24(20-28)[c]	42	144(135-155)[c]	104(99-112)[c]	946	60
25	Sheep	39.1	V	7.44(7.32-7.54)[c]	7.6	32	20.5	26.2(21-28)[c]	38	153(146-161)[c]	103(98-109)[c]	967	57
26	Chicken	41.7	V	7.54(7.45-7.63)[c]	6.8	32		23(21-26)[c]	26	154(148-161)[c]	117(109-120)[c]	960	36
27	Alligator	5	H(M)	7.74	4.2	25	34.5	36.1	15		110	958	41
28		26	H(M)	7.30(6.87-7.66)[c]	4.3	22		18.8(15-27)[c]	38	144(130-148)[c]	107(83-128)[c]	952	50
29	Chameleon	26	H(M)	7.26(6.93-7.63)[c]	4.2	28		15.4(10-22)[c]	27	157(139-186)[c]	127(113-133)[c]	958	41
30	Iguana, black	26	H(M)	7.22(7.05-7.42)[c]	3.6	35		14.5(10-22)[c]	28	159(158-163)[c]	133(128-137)[c]	940	68
31	Snake, garter	26	H(M)	7.25(7.12-7.50)[c]		28		6.6(3-16)	22	156(143-169)[c]	130(122-143)[c]		50
32	Carp	20	H(V)	7.39(7.33-7.45)[c]	6.4	31		17.7(14-22)[c]	22	130(126-137)[c]	107(96-121)[c]	957	42
33	Skate	10.4	A	7.82	2.7	20	8.4		1.3	254(219-289)[c]	255(230-285)[c]	967	27

/1/ A=arterial blood, C=cutaneous; H=heart; M=mixed arterial and venous; V=venous. /2/ "Blood" pH is actually plasma pH. /3/ Assumed concentration of 20 mM hemoglobin per liter red cells. One mM (single Fe-atom structure, molecular weight 16,500) combines with 22.4 ml of O_2, S.T.P., when saturated. /4/ Total CO_2 concentration of oxygenated whole blood at pCO_2 of 40 mm (normal alveolar pCO_2 for many animals) and at body temperature, unless otherwise indicated. /5/ Calculated from pH and total CO_2 of plasma at body temperature by the Henderson-Hasselbalch equation. /6/ Venous blood.

Part II: CHLORIDE-BICARBONATE SHIFT

Exchange of Cl^- and HCO_3^- between red blood cells and plasma in tissues and lungs. Heavy arrows indicate the direction of the changes.



Part III: ACIDOSIS AND ALKALOSIS

Biochemical characteristics of uncompensated and compensated acidosis and alkalosis. + = increase; - = decrease; N = normal.

	Plasma	Normal Values	Acidosis: HCO_3^- Deficit Uncomp.	Acidosis: HCO_3^- Deficit Comp.	Acidosis: H_2CO_3 Excess Uncomp.	Acidosis: H_2CO_3 Excess Comp.	Alkalosis: HCO_3^- Excess Uncomp.	Alkalosis: HCO_3^- Excess Comp.	Alkalosis: H_2CO_3 Excess Uncomp.	Alkalosis: H_2CO_3 Excess Comp.
1	HCO_3^-	26(23-28) mM/liter; 58(51-62) vol %	--	-	+	+	++	+	-	-
2	CO_2 combining power	30(24-35) mM/liter; 65(53-78) vol %	--	-	+	+	++	+	-	-
3	H_2CO_3	1.3(1.1-1.5) mM/liter; 2.9(2.4-3.3) vol %	-	-	++	+	+	+	--	-
4	pCO_2	40(35-45) mm Hg	-	-	++	+	+	+	--	-
5	CO_2, total	28(24-33) mM/liter; 62(53-75) vol %	--	-	++	+	++	+	--	-
6	$\frac{HCO_3^-}{H_2CO_3}$	20	-	N	-	N	+	N	+	N
7	pH	7.4(7.35-7.45)	-	N	-	N	+	N	+	N
8	Urinary acidity and ammonia	<27 ml/kg 0.1 M acid (+NH$_3$)/24 hr	+	+	+	+	-	-	-	-

254. BLOOD GASES: MAN

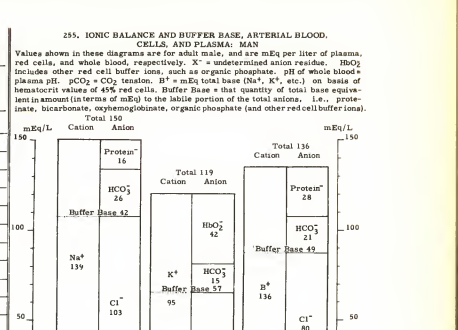
The values from which this table has been synthesized are in many instances derived by calculation from basic assumptions, factors, and constants, and do not have the same validity as measured values. Those for women are in general less well-founded than those for men. A = arterial blood; V = venous blood.

	Variable			Whole Blood: ml Gas in 100 ml Whole Blood	Whole Blood: ml Gas in ♂ 45.0 ml ♀ 40.0 ml RBC	Whole Blood: ml Gas in ♂ 55.0 ml ♀ 60.0 ml Plasma	ml Gas in 100 ml RBC (In Contact)	ml Gas in 100 ml Plasma (In Contact)	Blood Gas Pressure (Tension) mm Hg
1	Oxygen capacity		♂	20.4			45.3		
2			♀	18.0			45.3		
3	Total oxygen	A^1	♂	20.3	20.1	0.142	44.7	0.258	94
4			♀	17.9	17.7	0.155	44.7	0.258	94
5		V^1	♂	15.3	15.2	0.060	33.9	0.110	40
6			♀	13.7	13.6	0.068	34.4	0.113	41
7	"Free" oxygen	A	♂	0.285	0.144	0.142	0.319	0.258	94
8			♀	0.282	0.126	0.156	0.319	0.258	94
9		V	♂	0.122	0.061	0.061	0.136	0.110	40
10			♀	0.124	0.055	0.068	0.139	0.113	41
11	Combined oxygen (HbO_2)	A	♂	20.0	20.0	0	44.4	0	94
12			♀	17.6	17.6	0	44.4	0	94
13		V	♂	15.2	15.2	0	33.6	0	40
14			♀	13.6	13.6	0	34.3	0	41
15	Total carbon dioxide	A^1	♂	49.0	16.2	32.8	36.0	59.6	41
16			♀	48.0	13.6	34.4	34.3	57.0	39
17		V^1	♂	53.1	18.0	35.1	40.1	63.8	46
18			♀	51.4	14.9	36.5	37.7	60.4	43
19	"Free" carbon dioxide	A	♂	2.62	1.06	1.56	2.36	2.84	41
20			♀	2.53	0.89	1.64	2.25	2.72	39
21		V	♂	3.00	1.21	1.79	2.69	3.25	46.5
22			♀	2.78	0.96	1.82	2.44	3.01	43
23	Total combined carbon dioxide	A	♂	46.4	15.1	31.2	33.6	56.8	41
24			♀	45.5	12.7	32.8	32.1	54.3	39
25		V	♂	50.1	16.8	33.3	37.4	60.5	46.5
26			♀	48.6	14.0	34.7	35.3	57.4	43
27	Carbamino carbon dioxide	A	♂	2.2	1.7	0.4	3.9	0.8	41
28			♀	1.9	1.5	0.5	3.7	0.8	39
29		V	♂	3.1	2.6	0.5	5.8	0.8	46.5
30			♀	2.7	2.2	0.5	5.5	0.8	43
31	Bicarbonate carbon dioxide	A	♂	44.2	13.4	30.8	29.8	56.0	41
32			♀	43.6	11.2	32.3	28.3	53.5	39
33		V	♂	47.0	14.2	32.8	31.6	59.7	46.5
34			♀	46.0	11.8	34.2	29.8	56.6	43
35	Nitrogen	A & V	♂	0.979	0.494	0.484	1.099	0.881	572
36			♀	0.970	0.437	0.534	1.103	0.884	574

/1/ Difference between arterial and venous values for O_2 and CO_2 can vary, depending on vein from which blood was drawn, the presence of local vascular constriction or dilatation, degree of cold or warmth, or metabolic activity.

255. IONIC BALANCE AND BUFFER BASE, ARTERIAL BLOOD, CELLS, AND PLASMA: MAN

Values shown in these diagrams are for adult male, and are mEq per liter of plasma, red cells, and whole blood, respectively. X^- = undetermined anion residue. HbO_2 includes other red cell buffer ions, such as organic phosphate. pH of whole blood = plasma pH. pCO_2 = CO_2 tension. B^+ = mEq total base (Na^+, K^+, etc.) on basis of hematocrit values of 45% red cells. Buffer Base = that quantity of total base equivalent in amount (in terms of mEq) to the labile portion of the total anions, i.e., proteinate, bicarbonate, oxyhemoglobinate, organic phosphate (and other red cell buffer ions).



256. RESPIRATORY CHARACTERISTICS, ARTERIAL AND VENOUS BLOOD: MAN, ADULT AND NEWBORN

Adult values are averages of means. Ranges in parentheses are estimate "c" and "d", as indicated, of the 95% range (cf Introduction). A = arterial; V = venous. In the newborn (before first breath), where the oxygenated blood goes from the placenta to the fetus via the umbilical vein, A refers to the vena umbilicalis and V to the arteria umbilicalis.

	Measurement		Adult[1]	Newborn		Measurement		Adult[1]	Newborn
1	O_2 Tension, mm Hg	A	95. 2(80. 0–104. 0)c	24. 4(13. 5–34. 0)d	9	CO_2 Tension, mm Hg	A	41. 0(35. 0–47. 0)c	44. 9(35. 0–60. 0)d
2		V	39. 4(29. 5–48. 5)d	10. 4(1. 2–19. 0)d	10		V	43. 3(33. 0–54. 3)c	59. 2(43. 5–88. 0)d
3	O_2 Content, vol %	A	19. 4(17. 3–22. 3)c	10. 6(5. 6–17. 9)d	11	CO_2 Content, vol %	A	48. 9(42. 8–57. 1)c	40. 9(31. 2–51. 6)d
4		V	15. 0(12. 6–16. 4)c	2. 9(0. 4–8. 4)d	12		V	51. 2(45. 2–61. 5)c	48. 0(37. 4–55. 2)d
5	O_2 Capacity, vol %	A	20. 2(16. 8–23. 1)c	22. 2(17. 2–26. 2)d	13	pH	A	7. 426(7. 37–7. 49)c	7. 32(7. 23–7. 41)d
6		V	4. 6(3. 2–6. 0)c[2]	7. 2(2. 1–12. 5)d[3]	14		V	7. 40(7. 36–7. 47)c	7. 25(7. 14–7. 37)d
7	O_2 Saturation, %	A	96. 4(90. 5–101. 0)c	47. 7(25. 7–73. 8)d					
8		V	73. 3(63. 0–81. 9)c	13. 9(2. 4–37. 6)d					

/1/ Arterial blood from femoral or brachial artery, mixed venous blood from pulmonary artery. /2/ Arterio-venous O_2 difference. /3/ Venous-arterial O_2 difference.

257. H_2CO_3 DISSOCIATION CONSTANTS IN BLOOD, SERUM, AND RBC: MAN, OX, DOG[1]

	Medium	Temp °C	Dissociation Constant (pK)
1	Serum[2]	38	6. 11(6. 097–6. 122)[3]
2	Plasma	42	6. 067[4], 6. 073[5], 6. 063[6]
3		37	6. 094[4], 6. 098[5], 6. 088[6]
4		31	6. 114[4], 6. 116[5], 6. 107[6]
5		25	6. 124[4], 6. 125[5], 6. 120[6]
6	RBC Reduced	37	5. 98
7	Oxidized	37	6. 04

/1/ Same values found for all three forms.
/2/ Normal men. /3/ Range. /4/ At pH 7. 4.
/5/ At pH 7. 1. /6/ At pH 7. 6.

258. ATMOSPHERIC CHARACTERISTICS: VARIOUS ALTITUDES

	Altitude	Temperature			Pressure				O_2 Part. Press.	Weight	Density		Pressure
	ft	°C	°F	°K	atm	psi	mm Hg	in. Hg	millibars	mm Hg	lb/cu ft	g/ml	Ratio	Ratio
1	0	15, 0	59	288, 0	1, 000	14, 67	760, 0	29, 92	1013, 2	159, 2	0, 07651	$1,25x10^{-3}$	1, 00	1, 00
2	5, 000	5, 1	41, 2	278, 1	0, 835	12, 23	632, 3	24, 89	842, 9	132, 5		$1,08x10^{-3}$	$8,62x10^{-1}$	$8,32x10^{-1}$
3	10, 000	-4, 8	23, 3	268, 2	0, 690	10, 11	522, 9	20, 58	697, 1	109, 5	0, 05649	$9,22x10^{-4}$	$7,38x10^{-1}$	$6,88x10^{-1}$
4	15, 000	-14, 7	5, 5	258, 3	0, 566	8, 29	428, 6	16, 87	571, 4	89, 8		$7,86x10^{-4}$	$6,29x10^{-1}$	$5,64x10^{-1}$
5	20, 000	-24, 6	-12, 3	248, 4	0, 460	6, 76	348, 8	13, 75	465, 0	73, 1	0, 04075	$6,66x10^{-4}$	$5,33x10^{-1}$	$4,59x10^{-1}$
6	25, 000	-34, 5	-30, 2	238, 5	0, 372	5, 46	282, 0	11, 10	375, 9	59, 1		$5,60x10^{-4}$	$4,48x10^{-1}$	$3,71x10^{-1}$
7	30, 000	-44, 4	-48, 0	228, 6	0, 296	4, 36	225, 7	8, 88	300, 9	47, 3	0, 02861	$4,67x10^{-4}$	$3,74x10^{-1}$	$2,97x10^{-1}$
8	35, 000	-54, 3	-65, 8	218, 7	0, 236	3, 46	178, 6	7, 03	238, 1	37, 4		$3,87x10^{-4}$	$3,10x10^{-1}$	$2,39x10^{-1}$
9	40, 000	-55, 0	-67, 0	218, 0	0, 191	2, 72	140, 6	5, 54	187, 4	29, 4	0, 01872	$3,06x10^{-4}$	$2,45x10^{-1}$	$1,85x10^{-1}$
10	50, 000	-55, 0	-67, 0	218, 0	0, 115	1, 69	87, 4	3, 44	116, 5	18, 3	0, 01161	$1,90x10^{-4}$	$1,52x10^{-1}$	$1,15x10^{-1}$
11	60, 000	-55, 0	-67, 0	218, 0	0, 07	1, 05	54, 1	2, 13	72, 1	11, 3	0, 00720	$1,18x10^{-4}$	$9,41x10^{-2}$	$7,12x10^{-2}$
12	70, 000	-55, 0	-67, 0	218, 0	0, 044	0, 649	33, 6	1, 32	44, 8	7, 0	0, 00447	$7,30x10^{-5}$	$5,84x10^{-2}$	$4,42x10^{-2}$
13	80, 000	-55, 0	-67, 0	218, 0	0, 027	0, 403	20, 8	0, 82	27, 8	4, 3	0, 00277	$4,52x10^{-5}$	$3,62x10^{-2}$	$2,74x10^{-2}$
14	90, 000	-55, 0	-67, 0	218, 0	0, 017	0, 250	12, 9	0, 51	17, 2	2, 7	0, 00172	$2,80x10^{-5}$	$2,24x10^{-2}$	$1,70x10^{-2}$
15	100, 000	-55, 0	-67, 0	218, 0	0, 011	0, 155	8, 0	0, 31	10, 6	1, 7	0, 00107	$1,74x10^{-5}$	$1,39x10^{-2}$	$1,05x10^{-2}$
16	200, 000	33, 8	93, 0	306, 8	$3,2x10^{-4}$	$4,6x10^{-3}$	0, 24	$9,5x10^{-3}$	0, 32	0, 05		$3,28x10^{-7}$	$2,63x10^{-4}$	$3,14x10^{-4}$
17	300, 000	-2, 2	28, 0	270, 8	$7,3x10^{-6}$	$1,1x10^{-4}$	0, 0055	$2,2x10^{-4}$	0, 0073	0, 00011		$8,57x10^{-9}$	$6,86x10^{-6}$	$7,23x10^{-6}$

259. ARTERIAL BLOOD GASES AT ALTITUDE: MAN

Values in parentheses are estimate "b" of the 95% range (cf Introduction).

	Altitude[1]			Oxygen				Carbon Dioxide	
				Tension	Content[2]	Capacity[2, 3]	Saturation	Tension	Content
	ft	m	mm Hg	mm Hg	ml/100ml	ml/100ml	%	mm Hg	ml/100ml
	Simulated Ascent in Low-Pressure Chamber[4]								
1	0	0	760	94	21, 1	21, 5	98	41	49
2	5, 000	1, 524	632	66	19, 6	21, 5	91(87-95)	36, 5	
3	8, 000	2, 458	564	60	19, 1	21, 5	89(84, 5-93, 5)	37, 4	
4	10, 000	3, 048	523	53	18, 4	21, 5	85, 4(79-92)	35, 8	
5	12, 000	3, 658	483	52	18, 3	21, 5	84, 9(77-92, 5)	34, 8	
6	14, 000	4, 267	446	44	17, 0	21, 5	79, 2(71-87, 5)	35, 4	
7	16, 000	4, 877	412	41	16, 4	21, 5	76, 2(65-87, 5)	33, 8	
8	18, 000	5, 486	379	36	15, 3	21, 5	71, 2(57-85, 5)	31, 8	
9	20, 000	6, 096	349	35	15, 2	21, 5	70, 8(57, 5-84)	29, 4	
	Ascent to Altitudes Necessitating Use of Pure Oxygen[4]								
10	35, 000	10, 668	179		11, 8	21, 5	92(84-100)		
11	37, 500	11, 430	159	74	20, 2	21, 5	94	40, 6	46, 3
12	39, 300	11, 979	146	57	19, 1	21, 5	88, 7	39, 4	50, 0
13	40, 000	12, 192	141	55	18, 9	21, 5	88, 1(81-95)	35(26-44)	42, 7(35-50)
14	41, 000	12, 497	134	54	18, 6	21, 5	86, 4(85-88)	38, 1	44, 8
15	42, 000	12, 802	128	49	17, 8	21, 5	83(71-95)	40(36-44)	47, 1(45-50)
16	43, 000	13, 106	122	42	16, 9	21, 5	78, 5(65-92)		41, 5(31-52)
17	44, 000	13, 411	116	36	15, 5	21, 5	72, 2(58-86)	33, 2	44, 9
18	45, 000	13, 716	111		14, 6	21, 5	68(53-83)		
	Permanent Residents in Mountainous Regions								
19	492	150	746	90	20, 7	21, 7	95, 4	41	46
20	7, 840	2, 390	568	68	21, 2(18, 5-24)	23, 1(19-27, 5)	91, 7(86, 5-97)	37, 8(34-42)	41, 1(37-45)
21	10, 300	3, 140	517	66	21, 8(19-25)	24, 0(22-26)	91, 0(87-95)	36, 4(31-42)	39, 3(34, 5-44)
22	12, 238	3, 730	479	57	21, 9(18, 5-25)	25, 0(21, 5-28, 5)	87, 6(84, 5-91, 5)		36, 0(33-39)
23	14, 896	4, 540	431	47	23, 0(19, 5-26, 5)	28, 3(24-32, 5)	81, 4(75, 5-87)	34, 7(29-40)	33, 5(32-35)
24	15, 950	4, 860	413	46	23, 4(20, 5-26, 5)	29, 0(25-33)	80, 7(76-85)	33, 0(28-38)	34, 0(31-37)
25	17, 521	5, 340	387	43	23, 0	30, 2	76, 2	29, 3	31, 8
	Newcomers to Mountainous Regions[5]								
26	11, 319	3, 450	496	55	20, 5	24, 1	85	31	41
27	15, 421	4, 700	429	46	18, 7	24, 1	78	29, 3	38, 3
28	17, 521	5, 340	387	43	18, 6	24, 5	76, 2	27, 7	35, 0
29	20, 145	6, 140	347	35	16, 3	24, 9	65, 6	24, 2	30, 2

/1/ U. S. Standard Atmosphere. /2/ Combined oxygen only; does not include physically dissolved oxygen, /3/ Values in lines 1-18 assume a uniform hemoglobin content of 15, 8 g/100 ml, /4/ For a period not longer than one hour. /5/ Up to 16 days.

260. HEMOGLOBIN, SEA LEVEL AND ALTITUDE: MAN

Values are for residents unless otherwise indicated.

	Country	Place	Altitude		Hb Conc.[1]	Corp. Hb[2]
			ft	m	g/100ml	µg
1	U. S. A.	Portland, Ore.	<1300	<400	15, 8	29, 3
2	U. S. A.	New Orleans, La.	<1300	<400	15, 9	27, 2
3	U. S. A.	Omaha, Nebr.	<1300	<400	15, 0	32, 0
4	Argentina	Buenos Aires	<1300	<400	14, 8	27, 9
5	Germany	Jena	<1300	<400	16, 0	31, 6
6	Hawaii	Honolulu	<1300	<400	15, 1	29, 7
7	India	Calcutta	<1300	<400	14, 8	27, 6
8	Norway	Oslo	<1300	<400	16, 2	29, 3
9	Peru	Lima	<1300	<400	16, 0	31, 1
10	Switzerland	Zurich	1, 640	500	15, 0	30, 0
11	U. S. A.	Denver	4, 920	1, 500	16, 5	30, 4
12	So. Africa	Johannesburg	5, 900	1, 800	14, 7	24, 5
13	Mexico	Mexico City	7, 550	2, 300	17, 7	32, 9
14	Chile	Ollague[3]	12, 140	3, 700	17, 0	30, 7
15	Peru	Morococha	14, 760	4, 500	20, 8	33, 8
16	Chile	Qulicha	17, 390	5, 300	22, 6	30, 7
17	Chile	Punta[3]	20, 000	6, 100	18, 3	31, 7
18	India	Nanga Parbat[3]	22, 970	7, 000	24, 7	30, 5

/1/ = g hemoglobin per 100 ml blood. /2/ = µg hemoglobin per RBC. /3/ Sojourners.

Part I: ERYTHROCYTE AND HEMOGLOBIN VALUES AT ALTITUDE: MAN
Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

	Altitude ft	Exposure Time	RBC millions/cu mm		Altitude ft	Exposure Time	Hemoglobin g/100 ml		Altitude ft	Exposure Time	Hematocrit %
1	Gr. level	Resident	4.93(4.0-5.65)	39	Gr. level	Resident	15.1(13.1-17.4)	75	Gr. level	Resident	48.4(42.0-56.0)
2	1840	Resident	4.75	40	1800	Resident	14.3	76	5000	Resident	d 48.4(43.8-53.6)
3	2200	Resident	5.04	41	5000	Resident	d 16.5(15.0-18.3)	77		Resident	§ 43.2(37.5-46.1)
4		Resident	4.65	42		Resident	§ 14.5(12.7-15.7)	78	10,000	1 da	50.0(41.0-56.0)
5	5000	Resident	d 5.42(4.83-6.07)	43	5750	Resident	14.7	79		2 da	49.2(44.0-55.0)
6		Resident	§ 4.63(4.41-5.0)	44		3 wk	15.6	80		4 da	51.0(45.0-59.0)
7	5200	Resident	6.55	45	6000	Resident	15.0	81		5 da	50.6(47.0-58.0)
8	5750	Resident	5.99(5.12-6.82)	46	7450	Resident	d 17.7(14.4-20.1)	82		6 da	49.1(44.0-54.0)
9		3 wk	5.19	47		Resident	§ 15.2(12.8-17.7)	83		7 da	50.3(47.0-55.0)
10	7400	Resident	d 5.39(4.53-6.17)	48	7800	Resident	16.4	84		8 da	49.3(46.0-56.0)
11		Resident	d 5.01(4.27-6.01)	49	9500	Resident	16.9	85		9 da	50.4(42.0-56.0)
12	8650	Resident	5.44	50	10,000	1 da	16.7(12.7-19.6)	86		11 da	49.4(43.0-57.0)
13	9200	1-55 da	5.24(4.72-5.67)	51		2 da	16.0(14.0-18.3)	87		13 da	50.4(45.0-55.0)
14	10,000	1 da	5.34(4.32-6.40)	52		4 da	16.0(13.7-19.5)	88	12,240	Resident	54.1(47.8-65.4)
15		2 da	5.58(5.04-6.11)	53		5 da	16.5(14.6-20.0)	89	12,900	Resident	54.3(50.5-86.0)
16		3 da	5.48(4.34-6.90)	54		6 da	16.5(15.2-18.2)	90	14,900	2 da	50.6
17		4 da	5.60(4.14-6.95)	55		7 da	16.2(14.0-18.1)	91		4 da	50.5
18		5 da	5.70(4.37-6.75)	56		8 da	16.3(15.4-18.3)	92		6 da	52.1
19		6 da	5.60(4.91-6.29)	57		9 da	16.6(15.1-18.7)	93		7-21 da	55.6(50.5-63.0)
20		7 da	5.66(4.97-6.56)	58		11 da	15.6(13.3-17.3)				
21		9 da	5.87(5.22-6.72)	59		12 da	15.7(13.3-17.2)				
22		11 da	5.48(4.07-6.51)	60		13 da	16.0(14.2-18.8)				
23		13 da	5.47(4.44-6.54)	61	10,100	Resident	17.2				
24	10,740	Resident	5.82	62	10,300	Resident	16.7				
25	11,400	3 da	d 6.20	63	11,300	Resident	17.5				
26		4 da	§ 5.20	64	12,240	Resident	18.8(16.4-22.1)				
27	12,000	Resident	7.50	65	14,100	Resident	18.1				
28		1-7 da	5.54(4.74-5.92)	66	14,200	Resident	18.9				
29	12,200	Resident	5.67(4.70-6.28)	67	14,800	Resident	19.4(15.7-25.0)				
30	12,300	Resident	6.31	68	14,900	Resident	20.8(18.1-25.4)				
31	14,200	Resident	7.05	69		Arr.[1]	16.9				
32	14,800	Resident	6.46	70		2 da	18.4				
33		7-21 da	6.43	71		4 da	17.7				
34	14,900	Resident	6.66(4.80-10.4)	72		6 da	18.3				
35	15,500	2 hr-11 da	5.86(4.66-6.63)	73		1-3 wk	18.6				
36	17,500	Resident	7.37	74	17,500	Resident	22.9				
37		1-16 da	5.93(4.96-6.89)								
38	20,800	3 hr - 6 da	5.77(5.41-6.52)								

/1/ On arrival at altitude.

Part II: LUNG ALVEOLAR O_2, CO_2 AT ALTITUDE: ACCLIMATIZED MAN

	Altitude[1]		Bar. Press.	pCO_2	pO_2
	m	ft	mm Hg	mm Hg	mm Hg
1	Sea level	Sea level	760	38.0	106.0
2	305	1000	733	37.7	100.3
3	800	2600	690	37.0	96.0
4	1900	6200	610	33.6	79.5
5	2370	7780	573	30.7	
6	2800	9200	543	34.0	64.0
7	3050	10,000	522	30.5	61.9
8	3457	11,300	496	31.2	55.5
9	3820	12,500	489	30.0	58.0
10	4700	15,400	429	28.0	46.9
11	5340	17,500	401	25.6	42.3
12	6140	20,100	356	21.4	37.7
13	6460	21,200	331	17.7	42.5
14	6950	22,800	310	15.6	37.0

/1/ U. S. Standard Atmosphere.

Part III: CERTAIN RESPIRATION AND CIRCULATION CHARACTERISTICS AT SIMULATED ALTITUDES: MAN
Data compiled from tests in a low-pressure chamber in which the inspired oxygen was always 20.9%. Values in parentheses are percentages of ground level values. Ground level altitude = 540 ft above sea level.

	Simulated Altitude	Respiration Frequency, breaths/min							Ventilation Volume, l./min						
		Ground	After Exposure for (minutes):						Ground	After Exposure for (minutes):					
		Level	10	20	30	40	50	60	Level	10	20	30	40	50	60
1	12,000 ft	13	14	13	14	14	14	14	8.85	9.45	9.48	9.50	9.66	9.61	9.77
	[483 mm Hg]	(100)	(107.7)	(100)	(107.7)	(107.7)	(107.7)	(107.7)	(100)	(106.8)	(107.1)	(107.4)	(109.2)	(108.6)	(110.4)
2	16,000 ft	13	12	11	13	12	12	11	8.25	9.32	9.14	9.74	9.79	9.39	10.50
	[412 mm Hg]	(100)	(92.2)	(84.6)	(100)	(92.2)	(92.2)	(84.6)	(100)	(113.0)	(110.8)	(118.0)	(106.5)	(113.8)	(127.3)
3	18,000 ft	12	11	11	11	11	12	11	8.42	10.9	11.24	11.06	11.73	10.66	10.83
	[379 mm Hg]	(100)	(91.7)	(100)	(91.7)	(91.7)	(100)	(91.7)	(100)	(129.5)	(133.5)	(131.4)	(139.4)	(126.6)	(128.5)
4	20,000 ft	11	11	11	12	13			8.40	12.36	11.76	12.46	13.44		
	[349 mm Hg]	(100)	(100)	(100)	(109.1)	(118.2)			(100)	(147.1)	(139.9)	(148.3)	(159.9)		
5	22,000 ft	11	12	14	15				8.64	14.61	15.21	15.31			
	[321 mm Hg]	(100)	(109.1)	(127.3)	(136.4)				(100)	(169.0)	(176.0)	(177.1)			

	Simulated Altitude	Alveolar O_2, [CO_2], mm Hg							Pulse Rate, beats/min						
		Ground	After Exposure for (minutes):						After Exposure for (minutes):						
		Level	10	20	30	40	50	60	10	20	30	40	50	60	
1	12,000 ft	101.0	52.1	51.0	50.4	51.4	50.9	50.7	(113)	(115)	(113)	(106)	(104)	(99)	
	[483 mm Hg]	[37.6]	[35.4]	[35.1]	[34.9]	[34.5]	[34.3]	[34.0]							
2	16,000 ft	106.1	45.6	44.8	45.4	43.2	44.4	44.2	(111)	(110)	(103)	(103)	(101)	(105)	
	[412 mm Hg]	[34.9]	[30.8]	[30.0]	[28.6]	[29.4]	[28.2]	[28.0]							
3	18,000 ft	107.1	43.1	41.3	40.1	40.8	39.8	41.1	(107)	(109)	(108)	(111)	(108)	(104)	
	[379 mm Hg]	[35.0]	[28.4]	[27.3]	[27.0]	[26.2]	[26.2]	[25.1]							
4	20,000 ft	104.8	37.6	36.7	36.4	37.9			(124)	(112)	(117)	(107)			
	[349 mm Hg]	[35.3]	[26.6]	[24.4]	[24.4]	[23.4]									
5	22,000 ft	103.3	34.0	32.7	32.0				(131)	(126)	(124)				
	[321 mm Hg]	[35.3]	[25.1]	[24.6]	[23.5]										

Part IV: CERTAIN RESPIRATION AND CIRCULATION CHARACTERISTICS AT ALTITUDES: MAN
Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

	Altitude ft	Exposure Time min	Respiration Frequency breaths/min	Expiratory Minute Volume[1] l./min	Stroke Volume[2] ml	Work, Left Ventricle g/cm x 10^{-6}
1	6,10[3]		16.8(9.4-24.2)	6.50(4.14-8.86)	72.6(43.0-102.2)	67.4(31.4-103.4)
2	10,000	5	16.5(9.2-23.8)	6.17(4.55-7.79)	74.3(31.6-117.0)	81.2(32.7-129.7)
3		10	16.3(8.0-24.6)	7.10(5.06-9.14)	76.9(34.3-119.5)	76.4(16.8-136.0)
4	18,000	5	17.9(7.8-28.0)	8.59(4.33-12.77)	82.0(37.6-126.4)	98.1(17.4-178.8)
5		10	18.5(10.0-27.0)	8.06(5.42-10.70)	88.4(45.4-131.4)	105.3(37.6-173.0)
6		15	18.1(10.4-25.8)	8.10(4.92-11.28)	93.9(49.6-138.2)	94.5(32.6-156.3)
7		20	15.6(12.5-18.7)	7.09(3.85-10.33)	99.3(50.9-147.7)	106.9(31.4-182.4)

/1/ Total volume of air expired per minute. /2/ Amount of blood discharged from left ventricle with each contraction. /3/ Ground level.

Part V: PULSE RATE AND SYSTOLIC BLOOD PRESSURE IN CHRONIC HYPOXIA
(8660 FEET): MAN

	Age yr	Pulse Rate beats/min	Systolic Pressure mm Hg
1	7-10	σ81; ♀102	σ160; ♀150
2	10-20	σ83; ♀91	σ170; ♀180
3	20-30	σ75; ♀83	σ190; ♀200
4	30-40	σ72; ♀80	σ180; ♀140
5	50-60	σ81; ♀89	σ200; ♀220
6	60-70	♀84	σ180; ♀230

Values in parentheses are ranges and where accompanied by superscript, conform to "b" or "c\" estimate of the 95% range (cf introduction).

	Animal	RBC millions/cu mm	Hematocrit ml/100 ml	Reticulocytes % of total RBC	RBC Diameter[1] (dry film) μ	RBC Volume[2] cu μ	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration[3] g/100 ml RBC	RBC Hb Content[4] μμg	Platelets thousands/cu mm
1	Man, birth[5]	5.7(4.8-7.1)[c]	56.6	4.35(2.5-6.5)[c]		106.0	21.5(18.0-27.0)[c]	38.0	38.0	227(140-290)[c]
2	1 wk	5.3(4.5-6.4)[c]	52.7	1.12(0.1-4.5)[c]		101.0	19.6(16.2-25.5)[c]	37.2	37.0	235(150-320)[c]
3	2 wk	5.1(4.3-6.0)[c]	49.6	0.67(0.2-1.5)[c]		96.0	18.0(14.5-24.2)[c]	36.3	35.0	247(163-340)[c]
4	3 wk	4.9(4.1-6.0)[c]	46.6	0.63(0.2-1.3)[c]		93.0	16.6(13.2-23.0)[c]	35.6	34.0	267(177-367)[c]
5	4 wk	4.7(3.9-5.9)[c]	44.6	0.73(0.1-1.0)[c]		91.0	15.6(12.5-21.0)[c]	35.0	33.0	280(185-390)[c]
6	3 mo	4.5(3.8-5.8)[c]	38.9	1.2(0.5-3.1)[c]		85.0	13.3(10.8-18.0)[c]	34.2	30.0	315(200-428)[c]
7	5 mo	4.5(3.8-5.3)[c]	36.5	1.66(0.9-2.94)[c]		79.0	12.4(10.2-15.0)[c]	34.0	27.0	338(205-465)[c]
8	7 mo	4.6(3.9-5.3)[c]	36.2	1.38(0.72-2.3)[c]		78.0	12.3(10.0-15.0)[c]	34.0	27.0	340(205-470)[c]
9	9 mo	4.6(4.0-5.4)[c]	35.8	1.12(0.65-1.9)[c]		77.0	12.1(9.8-15.0)[c]	33.8	26.0	345(210-473)[c]
10	11 mo	4.6(4.0-5.5)[c]	35.5	0.97(0.62-1.8)[c]		77.0	11.9(8.4-14.9)[c]	33.5	26.0	345(212-470)[c]
11	3 yr	4.7(3.8-5.4)[c]	35.5			78.0	11.7(9.2-15.5)[c]	33.0	25.0	
12	5 yr	4.7(3.8-5.4)[c]	37.1			80.0	12.6(9.6-15.5)[c]	34.0	27.0	
13	7 yr	4.7(3.8-5.4)[c]	37.9			80.0	12.7(10.0-15.5)[c]	33.5	27.0	
14	9 yr	4.7(3.9-5.4)[c]	38.9			80.0	12.9(10.3-15.5)[c]	33.2	27.0	
15	11 yr	4.8(3.8-5.4)[c]	39.0			80.0	13.0(10.7-15.5)[c]	33.3	27.0	
16	>14 yr, male	5.4(4.6-6.2)[b]	47(40-54)[b]	1.5(0.1-3.8)	7.5(7.2-7.8)[b6]	87(78-104)[7]	15.8(14.0-18.0)[b]	33.5(27-40)[b]	29(25-34)[b]	409(273-545)
17	female	4.8(4.2-5.4)[b]	42(37-47)[b]	1.5(0.1-3.8)		87(74-98)[b]	13.9(11.5-16.0)[b]	33.5(30-40)[b]	29(24-33)[b]	409(273-545)
18	Pregnancy, 6 mo	4.0(3.5-4.8)[b]	37(32-42)[b]			92.0	11.4(10.2-14.0)[b]	31.0	28.5	
19	9 mo	4.2(3.7-5.0)[b]	37.5(33-43)[b]			89.0	12.0(10.8-14.4)[b]	32.0	28.5	
20	labor	4.4(4.0-5.0)[b]	39(34-44)[b]			89.0	12.6(11.2-15.0)[b]	32.0	28.6	
21	Post-partum, 10 da	4.5(4.0-5.0)[b]	40(35-45)[b]			89.0	12.8(11.4-15.4)[b]	32.0	28.4	
22	Buffalo, domestic	6.8	44.3(38-52)		5.5	72.0	13(11.0-15.2)	19.0	29.0	
23	Carp	0.84(0.65-1.13)	31.3(21-40)[b]			311(278-340)	10.5(9.4-12.4)[b]	33.5	72(63-78)	
24	Cat	8.0(6.5-9.5)	40(28-52)	0.2	6(5.0-7.0)	57(51-63)	11.2(7.0-15.5)	28(23-31)	14(12-16)	345(164-500)
25	Chicken	2.8(2.0-3.2)	35.5(24-43.3)		11.2±6.8	127(120-137)	34.5(N7.3-12.9)	29(27-30)	36.6(33-41)	
26	Chimpanzee	5.1(3.4-6.0)	41.6(24-51)		7.4	81.4(70-91)	12.3(6.5-15.1)	30.6(29-34)	24.5(20-27)	
27	Cow	8.1(6.1-10.7)[c]	40(33-47)[b]		5.9	50(47-54)	11.5(8.7-14.5)[b]	29.0		684(542-975)
28	Dog	6.3(4.5-8.0)	45.5(36-53)	0.7(0-2.7)	7(6.2-8.0)	66(59-68)	14.8(11.0-18.0)	33(30-35)	23(21-25)	461(188-960)[c]
29	Dogfish	0.073(0.06-0.09)	6.8(5.5-7.6)		23.7±17.0	946(650-1180)	1.4(1.0-1.8)	21(19-24)	201(126-282)	
30	Duck[8]	2.5(1.8-3.3)	14.8(9-21)	0.2(0.1-0.5)	12.8±6.6		4.8(9-21)[b]	38.1		
31	Eel	2.4			13.3±8.1	149.0	9.3			
32	Frog, bull	0.44	29.3(26.6-32.0)		24.8±15.3	679(625-716)	(10-12)	26.0	177.0	
33	Goat	16.0(13.3-17.9)	33(27.0-34.6)		4.0	19.4	6.0(5.8-11.4)	34(33-36)	6.4	
34	Guinea pig	5.6(4.5-7)	42(37-47)	0.9(0.4-1.8)	7.4(7.0-7.5)	77(71-83)	14.4(11-16.5)	34(33-35)	26(24.5-27.5)	783(525-900)
35	Hagfish	0.14(0.12-0.19)	22.2(19.3-27.6)			1530(1470-1560)	4.6(4.0-5.7)	21.0	318(303-330)	
36	Hamster	6.9(6.3-96.9)[c]	49(39-59)[c]	1.8(1.0-3.4)	5.6(5.4-5.8)	70.0	16(2-30)[c]	32.0	23.0	338(160-516)[c]
37	Horse	9.3(8.21-10.35)	33.4(28-42)[b]		5.5		11.1(8-14)[b]	33.0		335(249-461)
38	Lamprey	0.333			14.3	710.0	5.8			
39	Mackerel	3.9(3.6-4.2)	57.5(56-59)		12.4±8.3	146(140-152)	14.8(14.5-15.2)	26.0	37.5(36-39)	
40	Monkey, rhesus		42(32-52)[b]				12.6(10-16)	30.0		267(155-424)
41	Mouse	9.3(7.7-12.5)	41.5	4.0	6.0	49(48-51)	14.8(10-19)	36(33-39)	16(15.5-16.5)	278(246-339)
42	Pike	1.1(0.4-1.37)	(16-33.0)							
43	Rabbit	5.7(4.5-7.0)	41.5(33-50)	2.2(2-3)	7.5[9](6.5-7.5)	61(60-68)	11.9(8.0-15.0)	29(27-31)	21(19-23)	533(170-1120)[c]
44	Rat	8.9(7.2-9.6)[b]	46(39-53)	2.9(0.6-4.9)	7.5[9](6.0-7.5)	61(57-65)	14.8(12-17.5)	32(30-35)	17(15-19)	754(702-796)
45	Sea gull	2.6			13.7±8.1	126.4	10.2			
46	Sea robin	1.93			10.4±7.3	130.0	6.2			
47	Sheep	10.3(9.4-11.1)	31.7(29.9-33.6)		4.8	31(30-32)	10.9(10-11.8)	34.5	11.0	441(284-659)
48	Skate, barn door	0.265			21.9±15.6	727.0	3.6			
49	Snake, garter	1.05(0.71-1.39)	28(19-37)		18.1±10.3	267.0	8.5(5.8-11.3)	31.0	82.0	
50	Stingray	0.30			20.6±14.3	612.0	3.0			
51	Swine	6.4	41.5(30-53)[b]			63.0	13.3(10-16.5)[b]	35.0	22.0	403(296-616)
52	Trout	1.01(0.74-1.5)	27.2(22-36)			314(284-348)	8.5(6.2-11.5)	31.2	75(61-82)	
53	Turkey	2.3	38.0		♂15.5±7.5		11.2	23.5		
54	Turtle, box	0.647	25(21-27)[b]	2.0	9.0±19.0	442.0	7.2(6.1-9.1)[b]	20.6	91.0	

/1/ Ranges in parentheses are for diameter only. Values otherwise represent length x width. /2/ Mean corpuscular volume. /3/ Blood hemoglobin concentration = $\frac{\text{hematocrit}}{100}$. /4/ Blood hemoglobin concentration x $\frac{100}{\text{RBC}}$. /5/ Erythrocyte and hemoglobin values are higher during first week of life if cord is clamped after placental separation. /6/ In plasma = 8.4(7.4-9.4). /7/ Ordinary range of mean corpuscular volume among individuals, 81-95. /8/ As ducks mature, all hematologic values progressively increase, with the exception of reticulocytes which progressively decrease. /9/ In plasma.

Values are in thousands/cu mm; in most cases they are also given as per cent of total leukocytes. Ranges are in parentheses. Those on lines 1-18, 20, 22, 24 and 28-31 conform to estimate "di" of the 95% range (cf Introduction). Other values and ranges are approximate averages of highly variable unweighted means and ranges from the literature.

	Animal	Leukocytes Total	Neutrophils Total	Neutrophils Band[1]	Neutrophils Segmented	Eosinophils	Basophils	Lymphocytes	Monocytes
1	Man[2], birth	18.1(9.0-30.0)	11.0(6.0-26.0)	1.65	9.4	0.4(0.02-0.85)	0.1(0.0-0.64)	5.5(2.0-11.0)	1.05(0.4-3.1)
	%	100	61(40-80)	9.1	52	2.2	0.6	31	5.8
2	12 hr	22.8(13.0-38.0)	15.5(6.0-28.0)	2.33	13.2	0.45(0.02-0.95)	0.1(0.0-0.50)	5.5(2.0-11.0)	1.20(0.4-3.6)
	%	100	68(40-80)	10.2	58	2.0	0.4	24	5.3
3	24 hr	18.9(9.4-34.0)	11.5(5.0-21.0)	1.75	9.8	0.45(0.05-1.00)	0.10(0.0-0.30)	5.8(2.0-11.5)	1.10(0.20-3.1)
	%	100	61(40-75)	9.2	52	2.4	0.5	31	5.8
4	1 wk	12.0(5.0-21.0)	5.5(1.5-10.0)	0.83	4.7	0.50(0.07-1.10)	0.05(0.0-0.25)	5.0(2.0-17.0)	1.10(0.30-2.7)
	%	100	45(25-65)	6.8	39	4.1	0.4	41	9.1
5	2 wk	11.4(5.0-20.0)	4.5(1.0-9.5)	0.63	3.9	0.35(0.07-1.00)	0.05(0.0-0.23)	5.5(2.0-17.0)	1.00(0.20-2.4)
	%	100	40	5.5	34	3.1	0.4	4.8	8.8
6	4 wk	10.8(5.0-19.5)	3.8(1.0-9.0)	0.49	3.3	0.30(0.07-0.90)	0.05(0.0-0.20)	6.0(2.5-16.5)	0.70(0.15-2.0)
	%	100	35	4.5	30	2.8	0.5	56	6.5
7	2 mo	11.0(5.5-18.0)	3.8(1.0-9.0)	0.49	3.3	0.30(0.07-0.85)	0.05(0.0-0.20)	6.3(3.0-16.0)	0.65(0.13-1.8)
	%	100	34	4.4	30	2.7	0.5	57	5.9
8	4 mo	11.5(6.0-17.5)	3.8(1.0-9.0)	0.45	3.3	0.30(0.07-0.80)	0.05(0.0-0.20)	6.8(3.5-14.5)	0.60(0.10-1.5)
	%	100	33	3.9	29	2.6	0.4	59	5.2
9	6 mo	11.9(6.0-17.5)	3.8(1.0-8.5)	0.45	3.3	0.30(0.07-0.75)	0.05(0.0-0.20)	7.3(4.0-13.5)	0.58(0.10-1.3)
	%	100	32	3.8	28	2.5	0.4	61	4.8
10	8 mo	12.2(6.0-17.5)	3.7(1.0-8.5)	0.41	3.3	0.30(0.07-0.70)	0.05(0.0-0.20)	7.6(4.5-12.5)	0.58(0.08-1.2)
	%	100	30	3.3	27	2.5	0.4	62	4.7
11	10 mo	12.0(6.0-17.5)	3.6(1.0-8.5)	0.40	3.2	0.30(0.06-0.70)	0.05(0.0-0.20)	7.5(4.5-11.5)	0.55(0.05-1.2)
	%	100	30	3.3	27	2.5	0.4	63	4.6
12	12 mo	11.4(6.0-17.5)	3.5(1.5-8.5)	0.35	3.2	0.30(0.05-0.70)	0.05(0.0-0.20)	7.0(4.0-10.5)	0.55(0.05-1.1)
	%	100	31	3.1	28	2.6	0.4	61	4.8
13	2 yr	10.6(6.0-17.0)	3.5(1.5-8.5)	0.32	3.2	0.28(0.04-0.65)	0.05(0.0-0.20)	6.3(3.0-9.5)	0.53(0.05-1.0)
	%	100	33	3.0	30	2.6	0.5	59	5.0
14	6 yr	8.5(5.0-14.5)	4.3(1.5-8.0)	0.25(0.0-1.0)	4.0(1.5-7.0)	0.23(0.0-0.65)	0.05(0.0-0.20)	3.5(1.5-7.0)	0.40(0.0-0.8)
	%	100	51	3(0.0-10)	48(16-60)	2.7	0.6	42	4.7
15	10 yr	8.1(4.5-13.5)	4.4(1.8-8.0)	0.24(0.0-1.0)	4.2(1.8-7.0)	0.20(0.0-0.60)	0.04(0.0-0.20)	3.1(1.5-6.5)	0.35(0.0-0.8)
	%	100	54	3(0.0-10)	51(16-60)	2.4	0.5	38	4.3
16	14 yr	7.9(4.5-13.0)	4.4(1.8-8.0)	0.24(0.0-1.0)	4.2(1.8-7.0)	0.20(0.0-0.50)	0.04(0.0-0.20)	2.9(1.2-5.8)	0.38(0.0-0.8)
	%	100	56	3(0.0-10)	53(16-60)	2.5	0.5	37	4.7
17	18 yr	7.7(4.5-12.5)	4.4(1.8-7.7)	0.23	4.2	0.20(0.0-0.45)	0.04(0.0-0.20)	2.7(1.0-5.0)	0.40(0.0-0.8)
	%	100	57	3.0	54(25-70)	2.5	0.5	35	5.2
18	21 yr	7.4(4.5-11.0)	4.4(1.8-7.7)	0.22(0.0-0.7)	4.2(1.8-7.0)	0.20(0.0-0.45)	0.04(0.0-0.20)	2.5(1.0-4.8)	0.30(0.0-0.8)
	%	100	59	3(0.0-6)	56(37-75)	2.7	0.5	34	4.0
19	Cat	16.0(9.0-24.0)	9.5(5.5-16.5)			0.85(0.2-2.5)	0.02(0.0-0.1)	5.0(2.0-9.0)	0.65(0.05-1.4)
	%	100	59.5(44-82)			5.4(2-11)	0.1(0.0-0.5)	31(15-44)	4.0(5.7-7.0)
20	Cow	(5-12)	(1.2-4.8)			(0.18-1.8)	(0.0-0.1)	(2.7-6.9)	(0.15-1.8)
21	Dog	12.0(8.0-18.0)	8.2(6.0-12.5)			0.6(0.2-2.0)	0.09(0.0-0.30)	2.5(0.9-4.5)	0.65(0.3-1.5)
	%	100	68(62-80)			5.1(2-14)	0.7(0.0-2.0)	21(10-28)	5.2(3.0-9.0)
22	Goat	(5-14)	(2.1-3.4)			(0.0-1.1)	(0.0-0.6)	(2.1-11.3)	(0.05-0.60)
23	Guinea pig	10.0(7.0-19.0)	4.2(2.0-7.0)[3]			0.40(0.2-1.3)	0.07(0.0-0.30)	4.9(3.0-9.0)	0.43(0.3-2.0)
	%	100	42(22-50)			4.0(2-12)	0.7(0.0-2.0)	49(37-64)	4.3(3-13)
24	Horse	(5-11)	(3.0-6.9)			(0.09-0.60)	(0.0-0.1)	(1.2-4.8)	(0.1-1.5)
25	Mouse	8.0(4.0-12.0)	2.0(0.7-4.0)			0.15(0.0-0.5)	0.05(0.0-0.10)	5.5(3.0-8.5)	0.30(0.0-1.3)
	%	100	25.5(12-44)			2.0(0.0-5.0)	0.5(0.0-1.0)	68(54-85)	4.0(0.0-1.5)
26	Rabbit	9.0(6.0-13.0)	4.1(2.5-6.0)[3]			0.18(0.0-0.4)	0.45(0.15-0.75)	3.5(2.0-5.6)	0.7(0.3-1.3)
	%	100	46(36-52)			2.0(0.5-3.5)	5.0(2.0-7.0)	39(30-52)	8.0(4-12)
27	Rat	14.0(5.0-25.0)	3.1(1.1-6.0)			0.3(0.0-0.7)	0.1(0.0-0.20)	10.2(7.0-16.0)	0.3(0.0-0.65)
	%	100	29(9-34)			2.2(0.0-6.9)	0.5(0.0-1.5)	73(65-84)	2.3(0.0-5.0)
28	Sheep	(4-10)	(1.0-4.5)			(0.05-0.70)	(0.0-0.20)	(2.5-7.0)	(0.05-0.80)
29	Swine	(7-20)	(2.4-10.0)			(0.05-2.0)	(0.0-0.80)	(3.2-12.0)	(0.05-2.0)
30	Chicken	(16-40)	(4.0-16.0)			(0.4-4.0)	(0.2-1.6)	(8.0-24.0)	(1.0-6.0)
31	Duck						1.0(0.0-4.5)	45.8(13.0-73.5)	4.4(0.5-11.5)

/1/ Includes a small percentage of myelocytes during the first several days after birth. /2/ Values and ranges from birth through 12 months are from fragmentary data. A few prolymphocytes may be found in the blood of healthy infants up to 4 years of age. /3/ Cells classed as "neutrophils" include "pseudoeosinophils," "amphophils" or "heterophils."

Heart rates are widely variable and influenced by such conditions as breed, sex, age, environment, size, temperature and many others. Although temperature is particularly important in determining invertebrate heart rates, it is not specified in many of the literature sources. Ranges are given in parentheses and correspond with estimate "d" of the 95% range (cf Introduction).

	Animal	Beats/min	
	VERTEBRATES		
	Mammalia		
	Man (Homo sapiens)		81
1	Embryo, 5 mo	156(150-160)	82
2	6 mo	154(141-155)	83
3	7 mo	149(118-156)	84
4	8 mo	142(129-152)	85
5	9 mo	146(131-173)	86
6	Newborn, premature	(110-185)	
7	Newborn	134(101-160)	87
8	2 yr	108(84-134)	
9	4 yr	103(80-133)	88
10	6 yr	93(72-128)	89
11	8 yr	89(72-114)	90
12	10 yr	87(56-106)	91
13	15 yr	83(66-112)	92
14	20 yr	71(59-99)	93
15	20-24 yr	74(41-100)	94
16	25-30 yr	72(52-102)	95
17	30-35 yr	70(58-104)	96
18	35-40 yr	72(56-100)	97
19	40-45 yr	72(50-104)	98
20	45-50 yr	72(49-100)	99
21	50-55 yr	72(52-94)	100
22	55-60 yr	75(48-108)	101
23	60-65 yr	73(54-100)	102
24	65-70 yr	75(52-96)	103
25	70-75 yr	75(54-104)	104
26	75-80 yr	72(50-94)	105
27	80 and over	78(63-98)	106
28	Recumbent	66(40-100)	107
29	Sitting	73(31-110)	
30	Standing	82(54-124)	108
31	Sleeping	♂ 59, ♀ 65	109
32	Waking, male	78(61-119)	110
33	Waking, female	84(67-121)	
34	Ass (Equus asinus)	50(40-56)	111
35	Badger (Taxidea taxus)	138(128-144)	112
36	Bat (Plecotus auritus)	750(100-970)	113
37	Beaver (Castor canadensis)	140	114
38	Camel (Camelus bactrianus)	30(25-32)	115
39	Cat (Felis catus)	120(110-140)	116
40	Newborn	(168-300)	117
41	Cattle (Bos taurus)	70(40-100)	118
42	Chipmunk (Eutamias minimas)	684(660-702)	119
43	Dog (Canis familiaris)	(100-130)	120
44	Newborn	(160-180)	121
45	Dolphin (Delphinus spp)	150	122
46	Dormouse (Muscardinus sp)	646(580-780)	123
47	Elephant (Elephas maximus)	35(22-53)	124
48	Ferret (Mustela vison)	231(216-242)	125
49	Giraffe (Giraffa camelopardalis)	66	126
50	Goat (Capra hircus)	90(70-135)	127
51	Newborn	(145-240)	
52	Guinea pig (Cavia porcellus)	280(260-400)	128
53	Hamster (Cricetus cricetus)	450(300-600)	129
54	Hedgehog (Erinaceus europeus)	300(189-320)	
	Hibernating	(3-15)	130
55	Horse (Equus caballus)	44(23-70)	
56	Newborn	(100-120)	131
58	Hyena (Hyaena hyaena)	(55-58)	132
59	Lemming (Dicrostonyx hyhricatus)	416(348-465)	133
60	Lion (Panthera leo)	40	134
61	Manatee (Trichechus spp)	(50-60)	135
62	Marmot (Marmota marmota)	180(120-206)	136
63	Monkey (Macaca mulatta)	192(165-240)	137
64	Mouse (Mus musculus)	600(328-780)	138
65	Mouse, deer (Peromyscus sp)	534(324-858)	139
66	Opossum (Didelphis virginiana)	(120-240)	140
67	Panther (Felis concolor)	60	141
68	Porcupine (Erethizon dorsatus)	(280-320)	
69	Porpoise (Tursiops truncatus)	150	142
70	Rabbit (Oryctolagus cuniculus)	205(123-304)	143
71	Rat (Rattus spp)	428(261-600)	144
72	Newborn	(161-81-241)	
73	Seal (Phoca vitulina)	100(10-140)	145
74	Sheep (Ovis aries)	75(60-120)	146
75	Shrew (Blarina brevicauda)	699(618-780)	147
76	Shrew (Sorex cinereus)	782(588-1320)	148
77	Skunk (Mephitis mephitis)	166(144-192)	149
78	Squirrel (Sciurus vulgaris)	354(320-372)	150
79	Squirrel (Citellus spp)	249(96-378)	151
80	Swine (Sus scrofa)	(55-86)	152

	Animal	Beats/min	
	VERTEBRATES (continued)		
	Mammalia (concluded)		
88	Blackbird (Turdus merula)	(390-590)	162
89	Bramblefinch (Fringilla sp)	(900-920)	163
90	Buzzard (Buteo sp)	300(206-351)	164
91	Canary (Serinus canarius)	(514-1000)	165
92	Cassowary (Casuarius galeatus)	70	166
93	Chaffard (Sumetsilla sp)	330(318-354)	167
94	Cardinal (Richmondena sp)	(375-800)	168
95	Chaffinch (Fringilla coelebs)	700	169
96	Chickadee (Parus atricapillus)	(480-1000)	170
97	Cowbird (Molothrus sp)	(315-779)	171
98	Crane (Arthropoides paradizea)	120	172
99	Crow (Corvus corax)	378(312-492)	173
100	Dove (Columba spp)	282(185-300)	
101	Duck (Anas spp)	268(212-317)	174
102	Falcon (Falco sanchris)	367	175
103	Finch (Carduelis elegans)	920(914-925)	176
104	Fowl (Gallus spp)	312(178-458)	177
105	Goose (Anser a. domesticus)	(80-144)	178
106	Goshawk (Accipiter gentilis)	347	179
107	Greenfinch (Chloris hortensis)	740(703-848)	180
	Gull (Larus canus)	401(360-483)	182
	Hawk (Astur palumbis)	347	183
	Hummingbird (Archilochus colubris)	615[1]	185
	Jackdaw (Corvus monedula)	342(326-358)	
	Kestrel (Tinnunculus alaudarius)	367	
	Kingfisher (Alcedo ispida)	460	186
	Kite (Milvus spp)	258	187
115	Ostrich (Struthio camelus)	(60-70)	188
116	Parrot (Psittacus erithacus)	320	189
117	Penguin (Aptenodytes spp)	240	190
118	Pigeon (Columba spp)	170(141-244)	191
119	Redstart (Ruticilla phoenicurus)	890	192
120	Robin (Turdus migratorius)	370(320-420)	193
121	Rook (Corvus frugilegus)	380(352-440)	194
122	Sparrow (Passer domesticus)	804(745-850)	195
123	Sparrow, esp (Melospiza sp)	(450-1020)	196
124	Starling (Sturnus vulgaris)	388(375-400)	197
125	Stork (Ciconia sp)	161	198
126	Swan (Rhenelidae olor)	257	199
127	Thrasher, brown (Toxostoma sp)	278(270-294)	201
128	Titmouse (Parus major)	870	202
129	Towhee (Pipilo erythrophthalmus)	(445-810)	
130	Turkey (Meleagris gallopavo)	211(93-330)	205
131	Vulture (Gyps fulvus)	199	206
132	Wren (Troglodytes sedon)	(450-950)	207
	Reptilia		208
133	Adder (Bitis sp)	40	209
134	Adder (Tropidonotus natrix)	(23-68)	210
135	Blindworm (Anguis fragilis)	64	211
136	Crocodile (Crocodilus acutus)	(10-70)	212
137	Lizard (Lacerta viridis)	64(60-66)	213
138	Ringsnake (Coluber natrix)	(23-41)	214
139	Tortoise (Testudo spp)	(11-60)	215
140	Turtle (Emys orbicularis)	(6-9)	216
141	Turtle (Terrapene spp)	(6-70)	217
	Amphibia		218
142	Frog (Rana pipiens)	(4-50)	219
143	Salamander (Salamandra spp)	(30-40)	220
144	Toad (Bufo spp)	(40-50)	221
	Pisces		222
145	Barbel (Barbus fluviatilis)	(35-90)	223
146	Bass (Micropterus salmoides)	20(5-50)	224
147	Blenny (Zoarces viviparus)	(71-86)	225
148	Bullhead (Ameiurus sp)	22(5-50)	226
149	Carp (Cyprinus sp)	(40-78)	
150	Chub (Leuciscus dobula)	18	227
151	Cod (Gadus morhua)	(26-40)	228
152	Dragonet (Callionymus lyra)	(60-84)	229
			230

	Animal	Beats/min
	VERTEBRATES (concluded)	
	Pisces (concluded)	
153	Eel (Anguilla spp)	(39-68)
154	Eel, marine (Conger conger)	(33-50)
155	Goldfish (Carassaus auratus)	(36-40)
156	Gurnard (Trigla hirundo)	(62-86)
157	Haddock (Melanogrammus sp)	(30-40)
158	Perch (Perca fluviatilis)	(52-66)
159	Pike (Esox lucius)	(52-60)
160	Plaice (Pleuronectes platessa)	(54-76)
161	Pogge (Agonus cataphractus)	(61-90)
162	Ray (Tetrunarce spp)	(16-50)
163	Rockling (Montella mustela)	(64-82)
164	Scorpion fish (Scorpena scrofa)	(11-24)
165	Sculpin (Cottus scorpius)	(55-74)
166	Shad, gizzard (Dorosoma sp)	20(5-50)
167	Shark (Carcharodon carcharias)	(18-30)
168	Shark (Squalus acanthias)	(16-50)
169	Skate (Raja spp)	(16-50)
170	Stickleback (Gasterosteus sp)	(60-100)
171	Tench (Tinca tinca)	(31-42)
172	Trout (Salmo trutta)	(30-46)
173	Wrasse (Labrus mixtus)	(40-81)
	Tunicates[2]	
174	Sea squirt (Molgula sp)	(43-80)
175	(Appendicularia sp)	250
176	(Ascidia depressa)	(31-33)
177	(A. mentula)	(16-20)
178	(Ciona intestinalis)	(17-32)
179	(Clavellina lepardiformis)	(23-50)
180	(Cyclosalpa pinnata)	(26-30)
182	(Perophora annectens)	43
183	(Phallusia mammillata)	(9-12)
185	(Pyrosoma giganteum)	(38-58)
184	(Salpa bicaudata)	(13-40)
185	(S. fusiformis)	(41-69)
	INVERTEBRATES	
	Arthropoda	
186	Aphid (Aphis sp)	74(66-80)
187	Beetle (Chrysopa sp)	(53-63)
188	Botfly (Gastrophilus equi), larva	(40-44)
189	Cockroach (Periplaneta sp)	(60-90)
190	Crab (Limulus polyphemus)	20(8-28)
191	Crab (Maia sp)	(25-46)
192	Crab, cocoa-nut (Porcellana sp), larva	170
193	Crayfish (Astacus marinus)	90(30-87)
194	Crayfish (Cambarus clarkii)	116(75-136)
195	Daphnia (Daphnia pulex)	(140-166)
196	Lobster (Homarus grammarus)	60(50-100)
197	Lobster, rock (Palinurus sp)	35(30-50)
198	Moth (Cossus cossus)	15
199	Moth (Sphinx ligustri), larva	61(39-82)
201	Shrimp (Mysis sp)	260(140-320)
202	Shrimp (Lysmata seticaudata)	175(50-200)
203	Silkworm (Bombyx mori), larva	(30-40)
203	Spider (Epeira diadema)	132(130-134)
	Mollusca	
204	Chiton (Cryptochiton sp)	(5-7)
205	Chiton (Ischnochiton sp)	(12-25)
206	Clam (Dreissensia polymorpha)	(30-60)
207	Clam (Pisidium sp)	(60-75)
208	Clam (Mya arenaria)	(5-14)
209	Cuttlefish (Sepia officinalis)	(18-40)
210	Cuttlefish (Loligo spp)	(60-80)
211	Mussel (Anodonta cygnea)	(2-29)
212	Mussel (Mytilus edulis)	(15-25)
213	Octopus (Octopus vulgaris)	(12-59)
214	Oyster (Ostrea edulis)	(25-30)
215	Sea hare (Aplysia sp)	(8-35)
216	Sea hare (Pterotrachea sp)	67(60-74)
217	Scallop (Pecten jacobeus)	(22-50)
218	Slug (Arcilonax agrestris)	(20-40)
219	Snail (Helix pomatia)	(10-60)
220	Snail (Haliotis tuberculata)	(40-45)
221	Snail (Valvata piscinalis)	100
222	Snail (Natica sp)	(5-7)
223	Snail (Bulla sp)	(10-18)
224	Snail (Limnaea auricularia)	142(100)
225	Snail, land (Helix hortensis)	40
226	Whelk (Sycotypus sp)	(5-8)
	Miscellaneous	
227	Clamworm (Nereis virens)	8
228	Earthworm (Lumbricus terrestris)	17(15-20)
229	Leech (Hirundo medicinalis)	6
230	Lugworm (Arenicola sp)	7(6-8)

/1/ Basal rate. /2/ Chordates, but neither vertebrates nor invertebrates.

265. ELECTROCARDIOGRAPHIC DEFLECTIONS: VERTEBRATES

P wave = 1st wave of the electrocardiogram (EKG) = auricular activation; Q wave = 1st downward wave of ventricular QRS complex = ventricular activation; R wave = 1st upward wave of QRS complex; S wave = 2nd downward wave of QRS complex; T wave = slow final wave of ventricular complex = restitution of the resting state in ventricles.

Part I: AMPLITUDE: MAN

Values are millimeters (1 mm = 0.1 mV). Values in parentheses conform to estimate "d" of the 95% range (cf Introduction).

	Lead[1]	Age yr	P Wave mm	Q Wave mm	R Wave mm	S Wave mm	T Wave mm
1	I	0-10	0.8(0.04-1.2)	0.3(0-1.4)	4.8(1.5-12.3)	2.2(0-6.0)	2.7(0.20-5.0)
2		12-16	0.94(0-2.0)	0.99(0-3.0)	6.35(1.0-16.0)	2.07(0-11.0)	2.65(1.0-6.0)
3		Adults	0.55(0-1.1)	0.33(0-1.5)	6.81(1.5-19.4)	1.67(0-5.0)	2.21(1.0-5.5)
4	II	0-10	1.0(0.4-2.0)	0.6(0-2.8)	10.1(4.3-18.2)	1.0(0-4.1)	3.4(0.3-6.3)
5		12-16	1.62(1.0-3.0)	1.18(0-2.5)	14.0(5.0-25.5)	2.25(0-7.0)	3.48[d ±] -8.5)
6		Adults	1.25(0.3-2.5)	0.43(0-2.0)	11.99(4.0-22.0)	1.53(0-8.0)	2.97(1.0-6.0)
7	III	0-10	0.5(-0.9 to 2.0)	1.0(0.0-5.7)	7.4(0.2-19.0)	2.0(0-11.0)	0.7(-2.0 to 3.4)
8		12-16	0.73(-0.5 to 2.0)	1.56(0-5.0)	9.0(1.0-26.5)	1.92(0-9.0)	0.89(-1.0 to 3.5)
9		Adults	0.80(-1.0 to 2.0)	0.54(0-2.0)	8.50(1.2-18.0)	1.27(0-13.0)	1.49(-1.3 to 3.0)
10	aVR	0-10	-0.8(-1.0 to -2.0)	2.5(0-11.4)	2.3(0-5.7)	1.2(0-11.0)	-2.8(-6.1 to -0.2)
11		12-16	-1.14(-2.0 to -0.5)	7.90(0-14.0)	1.40(-3.5)	10.0(0-15.0)	-2.85(-5.0 to 0)
12		Adults	-0.08(-1.5 to -0.1)	2.81(0-7.6)	0.76(0-3.0)	2.56(0-10.5)	-1.66(-3.3 to -0.8)
13	aVL	0-10	0.4(-0.7 to 1.0)	0.02(0-1.0)	2.4(0.2-4.7)	3.5(0-12.8)	1.3(-1.2 to 7.2)
14		12-16	0.28(-1.0 to 1.0)	1.36(0-6.0)	2.59(0-12.0)	3.98(0-20.1)	1.10(-1.0 to 5.0)
15		Adults	0.2(-1.0 to 1.2)	0.21(0-1.5)	1.13(0-7.0)	2.00(0-7.0)	0.05(-1.0 to 1.0)
16	aVF	0-10	0.8(0.5-1.5)	0.8(0-3.1)	8.3(1.8-18.0)	1.6(0-8.0)	2.0(-1.6 to 4.8)
17		12-16	1.18(0-2.0)	1.28(0-3.0)	10.9(3.0-23.0)	1.73(0-4.0)	2.28[d ±] -8.0)
18		Adults	0.7(-1.8 to 1.6)	0.29(0-1.2)	6.68(0-13.0)	0.80(0-6.5)	1.46(0.2-2.8)
19	V_1	0-10	1.0(0-1.9)	0.0(0.0-0.0)	8.5(1.8-15.7)	12.3(2.4-25.6)	-2.5(-6.8 to 1.7)
20		12-16	0.44[d ±] -1.5)	0.0(0.0-0.0)	5.62(0.5-16.0)	14.5(5.0-46.0)	-1.2(-4.0 to 7.5)
21		Adults	0.6(-0.8 to 1.6)	0.0(0.0-0.0)	2.3(0-7.0)	10.5(2.0-24.0)	1.23(-4.0 to 5.6)
22	V_2	0-10	1.0(0-1.8)	0.0(0.0-0.0)	10.8(3.3-23.4)	16.3(4.4-37.8)	-1.5(-6.2 to 5.6)
23		12-16	1.08[d ±] -2.0)	0.0(0.0-0.0)	9.13(2.0-20.0)	23.7(8.0-52.0)	6.0[++] -13.5)
24		Adults	0.8(0.2-1.6)	0.0(0.0-0.0)	4.7(0.0-12.0)	13.4(5.0-38.0)	6.22(0.3-11.0)
25	V_3	0-10	0.9(0-1.7)	0.05(0.0-0.1)	12.0(1.6-34.1)	14.3(1.5-26.9)	-0.2(-6.2 to 10.1)
26		12-16	1.02(0.5-1.5)	0.0(0.0-0.0)	11.66(2.5-26.0)	12.6(3.0-35.0)	5.6[++] -13.5)
27		Adults	0.6(0-1.8)	0.0(0.0-0.0)	8.6(2.0-27.0)	8.8(3.0-21.0)	6.26(0.4-12.0)
28	V_4	0-10	0.8(0-1.6)	0.2(0.0-2.0)	15.4(4.5-37.8)	11.9(0.0-28.0)	0.7(-2.0 to 1.4)
29		12-16	0.96(0.25-1.5)	0.0(0.0-0.5)	23.8(6.5-51.0)	6.0(0.5-17.0)	7.5[++] -17.0)
30		Adults	0.6(0.1-2.3)	0.76(0.0-2.0)	13.0(2.0-25.0)	5.4(0.5-14.0)	5.66(0.3-11.0)
31	V_5	0-10	0.7(0-1.3)	0.7(0.0-3.4)	15.9(6.7-37.5)	6.7(0.0-22.0)	0.6(0.0-1.0)
32		12-16	0.94(0.25-1.0)	1.31(0.0-4.1)	18.1(6.0-34.0)	3.0(0.0-7.0)	5.93(2.0-13.0)
33		Adults	0.06(0-2.4)	0.24(0.0-1.0)	10.7(3.0-21.0)	1.7(0.0-10.0)	4.59(0.2-9.6)
34	V_6	0-10	0.7(0.2-1.3)	0.8(0.0-3.7)	13.4(1.0-21.5)	4.2(0.0-23.1)	0.6(0.0-1.0)
35		12-16	0.73(0.25-1.0)	1.30(0.0-2.5)	13.8(5.0-20.0)	1.4(0.0-5.0)	3.98(1.0-7.0)
36		Adults	0.06(0-1.4)	0.49(0.0-2.0)	9.2(3.0-19.0)	0.42(0.0-5.0)	2.55(0.2-5.2)

[1] Leads: I = between right arm (R) and left arm (L); II = between right arm and left leg (F); III = between left arm and left leg; aVR = between point connected to (L) and (F) through large equal resistances and (R); aVL = between point connected to (R) and (F) through large equal resistances and (L); aVF = between point connected to (R) and (L) through large equal resistances and (F); V_1 = between central terminal (point connected to (R), (L), and (F)) through large equal resistances and 4th intercostal space (ICS) at right sternal border; V_2 = central terminal to 4th ICS at left sternal border; V_3 = central terminal to point midway between V_2 and V_4; V_4 = central terminal to 5th ICS at midclavicular line; V_5 = central terminal to anterior axillary line at ht of V_4; V_6 = central terminal to midaxillary line at ht of V_4.

Part II: DURATION: VERTEBRATES

Values are milliseconds and, except where noted, apply to adult animals.

	Species	P Wave[1] msec	P-R Interval[2] msec	QRS Interval[3] msec	$Q\text{-}T_c$[4, 5] msec
	Man				
1	0-1 da	52(40-68)	104(80-120)	65(40-100)	421
2	1 da-1 wk	49(36-68)	100(80-120)	56(40-80)	402(322-476)
3	1 wk-1 mo	48(40-60)	97(80-160)	55(40-70)	385(345-434)
4	1-3 mo	47(40-64)	100(80-120)	62(50-80)	397(304-500)
5	3-6 mo	52(48-64)	103(80-130)	68(50-80)	392(348-458)
6	6 mo-1 yr	55(40-70)	108(80-140)	65(40-80)	408(350-455)
7	1-3 yr	59(65-88)	115(80-150)	64(40-80)	394(338-455)
8	3-5 yr	67(40-96)	122(100-160)	69(40-96)	402(349-465)
9	5-8 yr	68(40-96)	130(100-180)	70(40-90)	414(350-514)
10	8-12 yr	73(40-100)	137(100-200)	74(50-96)	419(350-536)
11	12-16 yr	78(50-104)	146(100-200)	76(40-100)	408(302-455)
12	Adult ♂	90(70-120)	160(110-210)	83(50-100)	397(337-433)
13	♀	90(70-120)	160(110-210)	72(50-100)	415(380-456)
14	Bull	80	180(160-200)	50	310(300-320)
15	Cat	40	80(60-110)	30	(330-400)
16	Cow	110(100-120)	225(220-230)	80	350(260-410)
17	Dog	70(60-80)	120(70-150)	45(30-80)	220(200-240)
18	Donkey	80	200	60	(270-360)
19	Elephant	160(120-200)	350(280-410)	150(120-180)	600(590-790)
20	Goat	80	130(120-140)	50	290(260-320)
21	Guinea pig	40	65(60-100)	30(10-50)	(200-430)
22	Hamster		43(40-46)	21(19-23)	
23	Horse	195(170-220)	370(320-420)	100(80-120)	520(440-600)
24	Monkey		71(54-88)	31(20-44)	(330-400)
25	Mouse, white	20	43(39-47)	22(20-24)	320
26	Mule	101(83-143)[b]	259(227-293)[b]	87(80-97)[b]	440(404-469)[b]
27	Rabbit	40(30-50)	60(50-100)	30(15-40)	(280-360)
28	Rat, white	20	42(35-53)	10(8-13)	(170-190)
29	Sheep	38(20-40)	(80-140)	(50-70)	(240-360)
30	Spermophile		48(38-58)	28(26-30)	
31	Swine	(40-70)	130(120-140)	60(40-80)	250(220-280)
32	Whale		300	(90-120)	240
33	Frog	60	(200-400)	80	600
34	Elasmobranch		190(120-260)	50(40-60)	
35	Teleost		250(200-440)	50(40-160)	750(400-1000)

[1] Duration of P, measured from the beginning to the end of the P wave. [2] P-R interval measured from the beginning of the P wave to the beginning of the QRS complex and corresponding to the atrio-ventricular conduction. [3] QRS interval, measured from the beginning to the end of the QRS complex, and corresponding to duration of intraventricular conduction. [4] Q-T interval, measured from the beginning of the QRS complex to the end of the T wave. [5] $= \frac{Q\text{-}T}{\sqrt{\text{cycle length}}}$.

Values in parentheses are ranges and, where accompanied by superscript, conform to estimate "b" of the 95% range (cf Introduction).

	Species	Body Weight kg	Surface Area sq m	Physiological State	Heart Rate beats/min	Stroke Volume ml/beat	Oxygen Consumption L/min	Cardiac Output L/min	Cardiac Index L/sq m/min	Method
1	Man	18, 0	0, 82	Basal, age 5	96	23, 8		2, 28	2, 78	Wexler - Böger
2		31, 2	1, 19	Basal, age 10 1/2	90	36, 3		3, 27	2, 75	Wexler - Böger
3		66, 0	1, 79	Basal, age 16 1/3	60	86, 2		5, 18	2, 90	Wexler - Böger
4		68, 5	1, 85	Basal, age 25	65	78, 4		5, 10	2, 76	Wexler - Böger
5		70, 0	1, 83	Basal, age 33 1/3	68	62, 8		4, 27	2, 33	Wexler - Böger
6		72, 4	1, 85	Basal, age 47	72	55, 8		4, 02	2, 17	Wexler - Böger
7		69, 8	1, 79	Basal, age 60	80	57, 0		4, 55	2, 54	Wexler - Böger
8		65	1, 78[1]	Sitting			0, 285(0, 256-0, 309)	6, 6(4, 7-8, 0)	3, 7	Ind, Fick - CO_2
9				Standing[2]		29, 2(21, 9-35, 2)		2, 21(1, 61-2, 85)		Wexler - Böger
10			1, 84	Tilting to 70°			0, 248(0, 220-0, 272)	4, 86(3, 94-6, 20)	2, 7(2, 0-3, 9)	Direct Fick
11				Acute hypoxia, 760 mm Hg	59, 8	72, 7		4, 35		Broemser - Ranke
12				600 mm Hg	66, 8	76, 0		5, 08		Broemser - Ranke
13				376 mm Hg	75, 9	81, 3		6, 17		Broemser - Ranke
14				260 mm Hg	85, 7	105, 9		9, 08		Broemser - Ranke
15				Hemorrhagic shock	113	31	0, 154(0, 119-0, 223)	3, 5	2, 20(1, 38-2, 99)	Direct Fick
16				"Vagotonia"	40	42	0, 204	1, 7		Wexler - Böger
17				"Sympathetictonia"	106	110	0, 327	9, 1		Wexler - Böger
18				Bicycle ergometer						
		65	1, 78[1]	102 kg m/min			0, 630(0, 621-0, 638)	8, 8	4, 91	Ind, Fick- CO_2
19		68, 1[3]	1, 81[4]	Basal, age 23 1/2[5]	63, 3(49-80)	54, 9(29-72)		3, 43(2, 0-5, 3)	1, 90	Broemser - Ranke
20				Basal, 150 kg m/min[6]	77, 5(51-99)	78, 0(54-101)		6, 08(3, 3-8, 6)	3, 36	Broemser - Ranke
21				300 kg m/min[6]	86, 3(59-113)	88, 4(68-119)		7, 62(4, 6-10, 2)	4, 21	Broemser - Ranke
22				450 kg m/min[6]	97, 8(69-127)	108, 1(77-170)		10, 62(5, 9-17, 9)	5, 87	Broemser - Ranke
23		65	1, 78[1]	525 kg m/min			1, 369(1, 348-1, 390)	14, 1(13, 8-14, 4)	8, 0	Ind, Fick- CO_2
24		64	1, 75	840 kg m/min			2, 08(2, 05-2, 10)	19, 2(19, 0-19, 4)	11, 0	Acetylene
25		75	1, 98	1200 kg m/min			2, 92(2, 83-2, 98)	23, 9(23, 0-25, 1)	12, 1	Acetylene
26		75	1, 98	1680 kg m/min			3, 84(3, 79-3, 94)	33, 8(28, 9-37, 3)	17, 1	Acetylene
27				Treadmill, 6 MPH, 0°			2, 41(2, 120-2, 900)	21, 6(18, 3-27, 5)		Ind, Fick- CO_2
28				7 MPH, 0°			2, 657(2, 530-3, 530)	27, 0(22, 0-33, 0)		Ind, Fick- CO_2
29	Bass				20		(0, 05-0, 09)[7]			Physical
30	Cat	2, 5		Anesthetized		2, 0-2, 4		0, 271(0, 168-0, 352)	1, 55(0, 36-2, 74)[8]	Fick
31		4, 1		Basal[7]	178, 8	3, 15	0, 56			Wetterer
32	Catfish				19	0, 12-0, 2[8]				Physical
33	Chick embryo							(0, 3-1, 0)[b]		Physical
34	Cow				60	244		14, 6		
35	Dog	6, 4	0, 39[9]	Basal[10]			0, 057(0, 042-0, 068)	1, 12(0, 65-1, 57)	2, 9	Direct Fick
36		14, 4	0, 66[9]	Anesthetized				1, 82(1, 14-2, 59)[b]	2, 8(1, 97-4, 18)	Stew, NaCl
37		23, 9	0, 93[9]	Anesthetized				2, 66(2, 00-3, 32)[b]	2, 9	Stew, NaCl
38		11, 8[11]		Basal[12]	170, 5(123, 3-226, 0)	6, 91(4, 42-9, 74)		1, 18(0, 80-1, 59)		Wetterer
39		16, 1	0, 71[9]	Basal			0, 106(0, 063-0, 184)	2, 21(1, 20-3, 84)	3, 1	Direct Fick
40		15	0, 68[9]	Shivering			0, 234(0, 232-0, 236)	4, 49(3, 66-5, 31)	6, 6	Direct Fick
41		21, 6	0, 87[9]	Treadmill, 3 MPH, 0°			0, 459(0, 393-0, 616)	5, 30(4, 2-7, 8)	6, 1	Direct Fick
42		21, 5	0, 87[9]	Standing			0, 210(0, 193-0, 238)	3, 9(3, 6-4, 1)	4, 5	Direct Fick
43		21, 5	0, 87[9]	Treadmill, 3 MPH, 5°			0, 609(0, 598-0, 620)	5, 8(5, 7-5, 9)	6, 7	Direct Fick
44		21, 5	0, 87[9]	5 MPH, 10°			1, 402(1, 380-1, 420)	12, 15(12, 1-12, 2)	14, 0	Direct Fick
45	Dogfish				36	(0, 4-1, 5)		(0, 014-0, 054)		Physical
46	Ferret				227			0, 139(0, 082-0, 20)		Direct Fick
47	Goat, kid			Basal				(0, 13-0, 20)[13]		Cardiometer
48	mature	23, 7	0, 91[1]	Basal			0, 176(0, 078-0, 329)	3, 1(1, 37-5, 60)	3, 4	Direct Fick
49	Horse	283	4, 30[14]	Standing			1, 364	18, 8	4, 4	Direct Fick
50		283	4, 30[14]	Treadmill, 47, 6 m/min, 0°			2, 965	31, 4	7, 3	Direct Fick
51		342	4, 90[14]	56, 9 m/min, 6, 5°			4, 414(4, 315-4, 513)	53, 1(46, 6-59, 5)	10, 8	Direct Fick
52		342	4, 90[14]	Standing			2, 480	24, 0	4, 9	Direct Fick
53	Monkey, rhesus				120	8, 8		1, 06		
54	Rabbit, white	3, 2	0, 21	Anesthetized			0, 021(0, 014-0, 028)	0, 35(0, 26-0, 48)	1, 7	Direct Fick
55		4, 13[15]		Basal[16]	214, 5(169, 5-288, 5)	2, 48(1, 27-3, 79)		0, 53(0, 25-0, 75)		Wett. & Broem. - Ran.
56	Rat	0, 18	0, 03	Anesthetized		1, 3-2, 0[17]		0, 047(0, 015-0, 079)[b]	1, 6	Direct Fick

/1/ = 0, 11 x $W^{2/3}$. /2/ Average of 5 persons standing about 15 minutes. /3/ Range: 57, 3-80, 5. /4/ Range: 1, 65-2, 03. /5/ Range: 18-30. /6/ Duration 2 minutes. /7/ Chloral-urethane narcosis. /8/ Gram/200-400 gram weight of fish. /9/ = 0, 112 x $W^{2/3}$. /10/ Morphine. /11/ Range: 8-17. /12/ "Pernocton" narcosis. /13/ Expressed as L/kg. /14/ = 0, 10 x $W^{2/3}$. /15/ Range: 3, 0-5, 2. /16/ Urethane narcosis. /17/ Based upon 0, 5 ml/kg, animals weighing between 2, 5 and 4, 0 kg.

Part I: EFFECT OF POTASSIUM[1]

Heart: Man and Laboratory Animals	mEq per L	mg %	Blood Pressure (Not in relation to serum concentration)	Other Systems
Experimental and therapeutic administration / autointoxication in anuria (crush syndrome, renal disease or obstruction); occasionally in traumatic shock and adrenal insufficiency.	14	56		Increased excretion of sodium.
	13			
Cardiac arrest.	12	48	No blood pressure changes until failure from I-V block and arrest.	Potentiation of acetyl choline.
	11			
Intraventricular block.	10	40		Essential for synthesis of acetylcholine.
	9			Anti-curare at synapses; anti-fatigue in skeletal muscles.
A-V block, P waves disappear.				
	8	32	Local stimulating effect may produce reflex rise in BP (also EEG changes) with IV injection.	
S-T depression.	7			
	6	24		No influence on EEG until fall in BP
Increase in amplitude of T wave.				
	5			
Normal		Range		
	4	16		Patients conscious until death and in full possession of faculties.
Low amplitude or inverted T waves.	3			
	2	8		Muscular weakness in animals; familial periodic paralysis in man.
Congestive heart failure.				
Focal necrosis	1			
Cushing's syndrome; alkalosis. Administration of desoxycorticosterone acetate necessary.	0			

/1/ Values, unless otherwise indicated, are serum concentrations.

Part II: EFFECT OF CALCIUM[1]

Heart: Man	Heart: Experimental Animals	mEq per L	mg %	Blood Pressure and Other Effects
		50	100	
Therapeutic administration.	Experimental administration.			
		45	90	
Hyperparathyroidism (moderate elevation only).				
	Arrest (range 35-65) in mid systole-diastole.	40	80	No blood pressure change until heart failure.
		35	70	
	Second slowing phase in animals escaping ventricular fibrillation (not prevented by atropine).	30	60	
				Antagonism to potassium in heart.
	Ventricular fibrillation.	25	50	
Ventricular fibrillation (?) (digitalis synergy).				
	Phase of tachycardia (range 15-40).	20	40	Anti-curare, especially anti-magnesium.
	Phase of slowing A-V delay & block (range 8-30), prevented by atropine.	15	30	Diminished neuro-excitability.
Shortened R-T ratio.	Shortened R-T ratio.	10	20	
Marked slowing and short arrest.				
	Normal	5	10	Level
Lengthened R-T ratio hypoparathyroidism.				Increased neuro-excitability, tetany, convulsions.

Part III: EFFECT OF MAGNESIUM[1]

Heart: Man and Experimental Animals	mEq per L	mg %	Blood Pressure and Other Effects
	50		
	45	54	
Arrest in diastole (with continued artificial respiration).	40	48	Tetanus at 200 P/S, failure of corneal reflexes.
	35	42	Progressive peripheral vasodilatation with fall in BP to zero. Flushing, sensation of warmth/increase in skin temperature (made use of in test of circulation velocity).
	30	36	
	25	30	Tetanus at 40 P/S; respiratory failure. Above 20 mEq, life sustained only by artificial respiration. Anesthesia.
Moderate progressive decrease in rate.	20	24	
	15	18	
Said to prevent extrasystoles in man.			Tetanus at 20P/S.
Progressive lengthening of P-R interval.	10	12	Curarization: twitches and tendon reflexes fail at range 6-12 mEq.
	5	6	
Normal			Level (not known) Tetany.

Part IV: SUMMARY OF EFFECTS ON HEART: Ca, K, Na, Mg

+ = increased; - = decreased; ± = no effect, or unknown.

	Cardiac Property	Calcium		Potassium		Sodium		Magnesium	
		Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
1	Automaticity	-	±	-	±	±	+	-	±
2	Conductivity	±	±	-	±	±	±	-	±
3	Contractility	+	±	±	±	±	-	-	±
4	Excitability	+	-	-	±	±	±	-	±
5	Relaxation	-	±	+	±	±	+	+	±
6	Rhythmicity	+	±	-	±	±	+	-	±

Part V: EFFECT OF pH ON THE HEART: DOG

Similar results are observed in man.

	pH	Cardiac Rate beats/min	P-R Interval sec	Depolarization QRS in sec	Repolarization Process ST Segment	T Wave	Bazett's (K) $K = \frac{QT}{\sqrt{RR}}$
				Acid[3]			
1	7.4[4]	150	0.09	0.04	-0.5	+1.3	0.35
2	6.2	120	0.13	0.05	-3.5	+3.0	0.35
				Alkali[3]			
3	7.4[4]	150	0.09	0.04	-0.5	+1.2	0.35
4	8.0	100	0.11	0.04	-3.5	-4.0	0.35

/1/ Decrease in contractility and automaticity; death in cardiac arrest. /2/ Normal. /3/ Death usually from ventricular fibrillation; produces monophasic currents in animals and predisposes to cardiac arrythmias. /4/ May be prolonged in man due to Ca^{++} depression or low K.

Part I: VASCULAR PRESSURES: MAN

	Chamber or Vessel	Systolic mm Hg	Diastolic mm Hg	Mean mm Hg
1	Small veins[1]			18
2	Medium veins[2]			4-7
3	Venae cavae[3]			-5 to 5
4	Right atrium[3]	1-5	0-2	1-3
5	Right ventricle[3]	20-30	0-4	
6	Pulmonary artery[3]	20-30	8-12	15-18
7	Pulmonary capillary[3]			8-10
8	Left atrium[4]	8-12	5-9	8-10
9	Left ventricle[5]	90-130	2-8	
10	Aorta	90-130	60-90	70-115

/1/ From animal and human data. /2/ Direct measurement. /3/ Right heart catheterization. /4/ Transthoracic needle puncture. /5/ Direct measurement, open chest.

Part II: CAPILLARY BLOOD PRESSURE: VERTEBRATES

Values in parentheses are estimate "d" of the 95% range (cf Introduction). A = arterial; V = venous.

	Animal	Region		Pressure cm H_2O
1	Man	Nail bed of finger.	A	43.5(28.6-65.0)[1]
2			V	16.5(8.0-24.5)[1]
3		Skin, hyperemia.	A	66.0(71.0-93.0)
4			V	(54.5-66.5)
5		Skin, hypertensive.	A	48.5(10.1-95.1)
6			V	30.8(12.8-58.0)
7	Guinea pig[2]	Mesentery, veronal ether anesthesia.	A	38.5(31.0-69.0)
8			V	17.0(13.0-19.5)
9	Rat[2]	Mesentery.	A	30.0(22.0-34.0)
10			V	17.0(15.0-20.0)
11	Frog	Mesentery.	A	14.4(5.0-22.0)[3]
12			V	10.1(6.7-18.0)[3]
13		Muscle, normal, urethane.	A	14.9(11.0-18.0)
14			V	9.5(7.0-12.7)
15		Muscle, hyperemia.	A	20.1(17.0-26.0)
16			V	16.0(12.0-17.5)
17		Web, normal, urethane.	A	13.9(10.0-19.0)
18			V	9.6(8.5-13.0)
19		Web, normal, curare.	A	14.5(0.0-20.5)
20			V	10.0(8.5-15.5)
21		Web, hyperemia.	A	19.5(14.0-26.5)
22			V	16.5(15.0-17.5)

/1/ Varies directly with venous pressure as affected by hydrostatic pressure or venous obstruction. Varies directly with arteriolar vasodilatation as produced by emotion, heat, or trauma. Varies inversely with arteriolar vasoconstriction as produced by emotion or cold. Varies minimally in a single capillary with time and also from capillary to capillary. /2/ Decerebrate. /3/ Pithed.

Part III: RELATIONSHIP OF CENTRAL AND PERIPHERAL ARTERY PRESSURES: MAN

Values are expressed as percentage of pressure of aorta or subclavian near the aorta. Values are means.

	Condition and Measurement	Artery		
		Brachial	Radial	Femoral
	Supine, at rest			
1	Systolic	109	112	110
2	Diastolic	96	93	94
3	Mean	98	94	96
	Supine, during exercise			
4	Systolic	111	113	101
5	Diastolic	97	93	95
6	Mean	97	93	97
	70° Head-up tilt			
7	Systolic	111	115	123
8	Diastolic	98	95	98
9	Mean	99	98	100

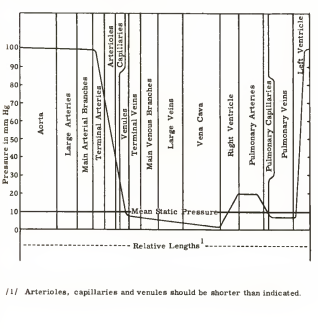
269. PULSE CHARACTERISTICS AND CONFIGURATIONS

Part I: PULSE WAVE VELOCITY FROM CENTRAL TO PERIPHERAL RECORDING SITE: MAN

	Recording Site	Velocity M/sec		Recording Site	Velocity M/sec
1	Aorta to radial artery	8.8(6.6-13.8)	3	Aorta to femoral artery	6.3(4.7-10.4)
2	Aorta to brachial artery	7.2(5.4-8.5)	4	Brachial artery to radial artery	12.5(9.3-22.5)

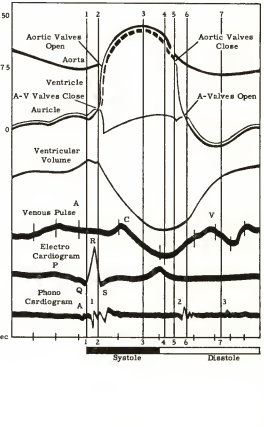
Part II: MEAN BLOOD PRESSURE AND VASCULAR INTERRELATIONS: DOG (SCHEMATIC)

Reference plane is 5 cm anterior to the dorsal surface with the animal supine; ranges are averages of those in the anesthetized dog during expiratory rest. The horizontal line at the level of 10 mm Hg is the pressure at each point during circulation arrest (mean static pressure).



/1/ Arterioles, capillaries and venules should be shorter than indicated.

Part III: CARDIAC CYCLE INTERRELATIONS



270. ARTERIAL BLOOD PRESSURE: MAN

Values are mm Hg. Ranges in parentheses are estimates of the 95% range, those on Lines 1-13 estimate "b," and those on Lines 14-26 estimate "a" (cf Introduction).

	Age	Male		Female			Age	Male		Female	
	yr	Systolic	Diastolic	Systolic	Diastolic		yr	Systolic	Diastolic	Systolic	Diastolic
1	Birth	74	38			24	16	118(95-142)	73(53-93)	116(92-140)	72(54-91)
2	4	89(78-100)	60(46-74)	89(76-102)	60(47-73)	25	17	121(98-144)	74(56-93)	116(93-139)	72(54-90)
3	5	92(80-104)	62(47-77)	92(79-105)	62(49-75)	26	18	120(96-143)	74(55-94)	116(94-139)	72(55-89)
4	6	94(81-107)	64(49-79)	94(80-108)	64(50-78)	27	19	122(92-151)	75(54-95)	115(92-138)	71(54-89)
5	7	97(84-110)	65(50-80)	97(83-111)	66(51-81)	28	20-24	123(98-150)	76(57-96)	116(93-139)	72(53-91)
6	8	100(87-113)	67(53-81)	100(86-114)	64(50-78)	29	25-29	125(100-150)	78(60-95)	117(94-139)	74(56-92)
7	9	101(88-114)	68(55-81)	101(87-115)	69(55-83)	30	30-34	126(99-153)	79(60-98)	120(92-147)	75(54-96)
8	10	103(90-116)	69(57-81)	103(89-117)	70(57-83)	31	35-39	127(99-155)	80(60-101)	124(97-151)	78(58-98)
9	11	104(91-117)	70(59-81)	104(90-118)	71(58-84)	32	40-44	129(100-159)	81(63-100)	127(94-161)	80(59-100)
10	12	106(93-119)	71(61-81)	106(92-120)	72(58-86)	33	45-49	130(97-163)	82(61-103)	131(92-169)	82(59-104)
11	13	108(95-121)	72(62-82)	108(95-121)	73(58-88)	34	50-54	135(97-172)	83(61-106)	137(96-179)	84(59-108)
12	14	110(97-123)	73(63-83)	110(97-123)	74(57-74)	35	55-59	138(101-175)	84(62-106)	139(97-180)	84(61-106)
13	15	112(98-126)	75(64-86)	112(98-126)	76(59-95)	36	60-64	142(100-183)	85(60-109)	144(100-188)	85(60-110)

271. ARTERIAL BLOOD PRESSURE: ANIMALS OTHER THAN MAN

Values are mm Hg. Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

	Species	Systolic	Diastolic
	VERTEBRATES		
	Mammals		
1	Bat[1]	50[2]	
2	Cat[2]	155	100
3	Cat, birth	(25-30)	
4	Cattle[3]	134(124-166)	88(80-102)
5	Cattle, young	130(110-140)[2]	
6	Dog[3]	148(108-189)	100(75-122)
7	Dog, birth	50	
8	Goat[3]	120(112-126)	84(76-90)
9	Guinea pig	(81-90)[2]	
10	Hamster[1]	(90-100)[2]	
11	Horse[1]	169(115-188)	
12	Horse, young	80	50
13	Horse, gelding[2]	98(90-104)	(57-71)
14	Horse, stallion	(70-98)	(40-58)
15	Horse, mare	(86-98)	(53-65)
16	Jackass	(90-104)	(54-60)
17	Mouse[3]	147(133-160)	106(102-110)
18	Opossum	(120-135)[2]	
19	Rabbit[3]	110(95-130)	80(60-90)
20	Rabbit, birth	35	
21	Rat	116(88-130)	90(60-100)
22	Rat, 20 ds embryo	12[2]	
23	Seal	(130-140)[2]	
24	Sheep	114(90-140)	68(64-76)
25	Sheep, 106 da embryo[2]	32[2]	
26	Swine	169(144-185)	108(98-120)

	Species	Systolic	Diastolic
	VERTEBRATES (continued)		
	Birds		
27	Buzzard	171[2]	
28	Canary[1]	220(200-250)	154(150-160)
29	Crow	(147-151)[2]	
30	Duck	162[2]	
31	Falcon	103[2]	
32	Fowl[3]	150	120
33	Goose	162(129-176)[2]	
34	Gull	179[2]	
35	Hawk	178[2]	
36	Jackdaw	119[2]	
37	Kite	194[2]	
38	Pigeon[5]	135(120-140)	105(100-115)
39	Red-hawk	103[2]	
40	Robin	118(110-125)	80
41	Rook	115[2]	
42	Sparrow[1]	180	140
43	Sparrow, fledgling[1]	(115-130)	
44	Starling[1]	180(150-210)	130(100-160)
45	Stork	161[2]	
46	Turkey	193[2]	
47	Vulture	171[2]	
	Amphibians and Reptiles[4]		
48	Bull-frog	(26-34)	(12-18)
49	Crocodile	(30-50)[2]	
50	Frog[2]	43(36-56)	31(24-44)
51	Snake, ring	89[2]	

	Species	Systolic	Diastolic
	VERTEBRATES (concluded)		
	Amphibians and Reptiles (concluded)		
52	Toad	48[2]	
53	Turtle[3]	44(38-55)	37(28-47)
	Fish		
54	Barbel	42[2]	
55	Bass, large mouth	50	40
56	Bullhead	22	13
57	Carp[3]	43(40-45)	
58	Catfish	37	23
59	Dogfish	32(30-37)	28
60	Eel	(65-70)[2]	
61	Pike	(35-84)[2]	
62	Ray	16	7
63	Salmon	75(47-120)	
64	Sand-shark	32	16
65	Shad, gizzard	48	38
66	Shark	(30-37)[2]	
67	Skate	20	
68	Torpedo	17(16-18)	10
	INVERTEBRATES		
69	Crab	4	
70	Earthworm	9.1[2]	
71	Lobster	10	
72	Mussel	3	
73	Octopus	60	
74	Sea-hare	(20-40)	
75	Squid	(25-80)	

/1/ Anesthetized. /2/ Mean pressure. /3/ Unanesthetized. /4/ Values change with body temperature, rising with raised temperature.

272. PULMONARY CIRCULATION DYNAMICS: MAN AND DOG

Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

	Condition	Pulmonary Pressure, mm Hg[1]			Venous[2]	Pulmonary Vascular Gradient mm Hg	Pulmonary Blood Flow L/min	Pulmonary Vascular Resistance (dyne sec)/(cm x 10^5)
		Arterial						
		Systolic	Diastolic	Mean				
					Man			
1	Resting	(23-25)[3]	(9-14)[3]	(14-18)[3]	(7-9)	(6-9)	(5.4-7.4)[3]	(67-238)[3,4]
2	Exercise, supine			(15[3]-21)	10	11	(9.6-10.4[3])	(90-115[3,4])
3	Exercise, standing[3]	26	9	16			12	76[4]
4	Hyperkia	26[3]	12[3]	(18[3]-20)	(7-8[3])	(10[3]-13)	(5.5-8.0[3])	(119[3]-189)
5	Saline infusion[3]			23	16	7	6.7	84
6	Epinephrine[3]			19	7	12	7.9	121
7	Norepinephrine	28	11	21	15	6	4.5	118
8	Tetraethylammonium chloride			15	10	5	4.7	85
					Dog			
9	Resting[5]			(17-18)	(4-10)	(8-13)	(2.3-3.2)	(285-325)
10	Hypoxia, moderate[5]			(22-26)	(4-8[6]	(14-22)	(2.4-3.8)	(463-467)
11	Hypoxia, severe[5]			26	9[6]	17	8.1	167

/1/ Zero point = 10 cm anterior to back in man; = back in dog. /2/ Pulmonary "capillary" mean pressure used except where indicated. /3/ Pressure approximately corrected to 10 cm zero point. /4/ Total pulmonary resistance, utilizing pulmonary arterial mean minus pulmonary "capillary" mean as pressure gradient. /5/ Anesthetized. /6/ Pulmonary venous or left atrial mean pressure.

Values in parentheses are ranges and, where accompanied by superscript, conform to the "b" or "c" estimate of the 95% range (cf Introduction).

	Species	Body Wt kg	Tissue or Organ	Physiological State	Tissue Weight		Blood Flow			% of Cardiac Output[5]
					kg	% body wt	ml/100g tissue per min[1,2]	ml/total tissue per min[2,3]	ml/sq m/min[2,4]	
1	Man	70	Total body, arterial (systemic circulation or cardiac output)	Basal	68.8	98.3	7.5(5.7-8.3)	5200	3000	100
2				Exercise			20.1	13,840	8000	100
3				Oligemic shock			4.5	3114	1800	100
4			Lungs (pulmonary circ.)	Basal	1.2	1.7	433(333-485)	5200	3000	100
5				Exercise			1153	13,840	8000	100
6				Oligemic shock			259	3114	1800	100
7			Adrenals	Basal	0.011	0.02	590	65	38	1.2
8			Brain	Basal	1.35	1.93	56(40-71)	729(540-959)		14.0
9				Inhalation 5-7% CO_2			93(65-141)			
10				85-100% O_2			45(34-55)			
11				10% O_2			73(39-107)			
12				Anesthesia, thiopental			61(33-117)			
13				Oligemic shock			32(26-38)	432(324-513)		
14				Sleep			65(48-85)			
15				Supine			64.7(50-103)			
16				Position change Supine			67.0(52-97)			
17				65^0 (head up)			53.1(40-81)			
18				Position change Supine (40^0-65^0)			65.1(52-97)			
19				Erect			51.6(40-81)			
20				L-Norepinephrine			61(42-83)			
21				L-Epinephrine			66(40-98)			
22				USP Epinephrine			71(42-97)			
23				Age, <45 yr			52(40-63)			
24				>45 yr			46(30-64)			
25			Heart (coronary circ.)	Basal	0.3	0.43	70(50-75)	210(150-225)	121	4.0
26				Exercise			576	1730	1000	12.5
27				Oligemic shock			86.5	259	150	8.0
28			Kidney	Basal	0.16	0.23	750(600-900)	1200(1000-1500)	696	23.0
29				Exercise[6]			415	1245	650	8.0
30				Oligemic shock[6]			28.8	86.5	50	3.0
31			Muscle	Basal	28.0	40.0	3.0(2.3-6.5)	850(500-1820)	491	16.3
32				Exercise			19.7	6920	4000	50.0
33				Oligemic shock			1.97	692	400	22.0
34			Liver, hepatic[7]	Basal	1.5	2.14	20.0	300	173	3.8
35			portal[7]				80.0	1200	695	23.1
36			Splanchnic flow[8]	Basal	1.843	2.63		1470	850	28.2
37				Exercise				1038	600	7.5
38				Oligemic shock				605	350	19.4
39			Extremities Hand[9]	Basal, 21^0C[10]			3.5(1.2-5.3)[c]			
40				24^0C[11]			5.9(2.7-9.6)[c]			
41				25^0C[10]			9.3(5.1-13.5)[b]			
42				21-24^0C[12]			2.1(0.5-6.4)[c]			
43				25-29^0C[12]			9.3(5.8-16.5)[c]			
44			Forearm	Basal, 15-20^0C[10]			2.3(1.2-3.0)[c]			
45				15-20^0C[13]			2.7(1.9-3.8)[c]			
46				15-20^0C[11]			4.2(1.5-7.0)			
47				$18,5^0$C[12]			3.1(2.6-3.6)[b]			
48				25-27^0C[14]			4.5(2.8-6.3)[c]			
49				27-29^0C[12]			4.9(1.7-7.3)[c]			
50			Calf	Basal, 25^0C[10]			1.4(0.4-2.4)[b]			
51			Foot	Basal, 21^0C[10]			2.0(0.5-4.4)[c]			
52				24-$26,5^0$C[10]			3.9(1.4-7.8)[c]			
53			Finger	Comfortable[12]			(15-40)			
54			Skin & subcutaneous	Basal	18.0[15]	25.71	1.4(1.2-1.8)	260(220-330)	150	5.0
55				Exercise			4.61	692	400	5.0
56				Oligemic shock			0.57	86.5	50	3.0
57			Thyroid	Basal	0.03	0.04	550	165	96	3.2
58	Monkey	3-6	Brain	Anesthesia, barbiturate			47(33-74)			
59				Hemorrhagic shock			24(13-30)			
60				Anesthesia, thiopental			24(14-26)			
61	Cat		Liver	Anesthesia			(33-48)			
62	Rat		Liver	Basal[16]			79(75-92)			
63	Dog	9-19	Heart	Basal	0.054[17]		133(79-220)	70.1(52-103)		
64		12-19	Liver	Basal	0.53		82(46-112)	387(216-612)		
65		10-16	Hind leg	Basal				55(35-75)		

/1/ = $\frac{\text{(ml/sq m/min x 1.73}}{\text{(ml/sq m/min) x 1.73}} \times \frac{1}{\text{organ wt}} \times 10$. /2/ Body surface 70 kg man = 1.73 sq m. /3/ = (ml/sq m/min) x 1.73. /4/ = $\frac{\text{(ml/100g tissue/mln) x (0.1 organ wt)}}{1.73}$.

/5/ = $\frac{}{\text{Cardiac output}}$. /6/ Values based on organ weight of 0.3 kg. /7/ Calculated from relative hepatic artery flow and portal vein flow as measured in dog. /8/ = portal drained viscera, including intestines, pancreas, spleen, stomach. /9/ Values for extremity flows are ml/min/100 ml segment. Water plethysmography, unless otherwise noted. /10/ Bath temp. 32^0C. /11/ Bath temp, 35^0C. /12/ Air plethysmography. /13/ Bath temp, 33^0C. /14/ Stewart dye principle. /15/ Skin, 4 kg; subcutaneous, 14 kg. /16/ Thermo-electric. /17/ Left ventricle alone.

274. CAPILLARY VASCULARITY, SKELETAL AND CARDIAC MUSCLE: VERTEBRATES

"Capillary" counts from injected cross-section may not exclude other minute vessels (e.g., arterioles, venules). By statistical estimation, numbers of arterioles per capillary per venules = 1/39/2.7 in membranous hamster cheek pouch in vivo; endothelial surface areas = 10/60/30; capacities = 21/18/61. By camera lucida drawings, endothelial surface areas = 21/25/54; capacities = 22/4/74.

Part I: SKELETAL MUSCLE

A = asphyxiated; R = resting; T = trained; U = untrained; V = vasodilated; W = working.

	Animal	Muscle		Capillaries per sq mm Cross-section[1, 2]	Capillaries per Fiber	Capillary Diameter[3] μ	Capillary Capacity[2, 4, 5] cu mm/cu mm	Capillary Surface Area[2, 5, 6] sq mm/cu mm
1	Cat	Gastrocnemius	V	2341		6.0	0.066	44.1
2		Rectus femoris	V	2474		6.0	0.070	46.6
3		Tibialis anterior	V	2214		6.0	0.063	41.7
4	Dog, adult	Semimembranosus	R	3240	0.6	7.1	0.128	72.3
5			V	5900	1.6	7.1	0.234	131.6
6			V	2630		7.2	0.107	59.5
7		Gracilis	R	1050	0.6	7.1	0.042	23.4
8			W[7]	2010	1.2	7.1	0.080	44.8
9			V	2580		7.1	0.102	57.5
10	Dog, puppy	Gracilis	R	1690	0.7	7.1	0.067	37.7
11	Guinea pig	Abdominal wall	R	85		3.0	0.001	0.8
12			R	270		3.8	0.003	3.2
13			V	1400		4.6	0.023	20.2
14		Diaphragm	W[8]	2570		5.0	0.050	40.4
15			W[8]V	3000		8.0	0.151	75.4
16		Gastrocnemius	R	1136		7.5	0.050	26.8
17			U	1378		7.5	0.061	32.5
18			T	1924		7.5	0.085	45.3
19			W[7]	2000		7.5	0.088	47.1
20			A	2600		7.5	0.115	61.3
21			V	2614		7.5	0.115	61.6
22	Mouse	Gastrocnemius	R	3060		6.6	0.105	63.4
23			W[7]	3600		6.6	0.123	74.6
24			A	4650		6.6	0.159	96.4
25		Masseter	W[7]	4393		6.6	0.150	91.1
26			W[7]V	5100		6.6	0.174	105.7
27			A	6800		6.6	0.233	141.0
28	Rabbit	Adductor magnus (white)	V	1550	0.7	2.5	0.008	12.3
29		Gastrocnemius	V	1344	1.6	11.9[9]	0.004	7.5
30		Gluteal	U		0.5	7.5		
31			T		1.2	7.5		
32		Semitendinosus (red)	V	790	1.2	5.2	0.017	13.0
33			V	1198	3.1	2.3[9]	0.005	8.8
34		Rectus femoris	V	1475	1.2	1.6[9]	0.003	7.4
35	Rat	Rectus femoris	V	3573		7.5	0.158	84.2
36		Tibialis anterior	V	3402		7.5	0.150	80.2
37	Frog (Rana temporaria)	Gastrocnemius	V	382	2.6	9.8	0.029	11.8
38		Gracilis	V	406	1.9	9.7	0.030	12.4
39		Obliquus oculi inferior	V	393	0.2	15.0	0.069	18.5
40		Sartorius	R	90		4.4	0.001	1.2
41			W[7]	325		6.8	0.012	7.0
42			V	400		15.0	0.071	19.0
43			V	426	1.8	8.6	0.025	11.5
44		Submaxillarus	V	652	0.7	11.1	0.063	22.7
45	Trout	Eyeball muscle	W[8]	276		10.6	0.024	9.2
46		Parietal	R	123		9.8	0.009	3.8
47		Rectus lateralis	W[8]	400		8.3	0.022	10.4

/1/ Differences in counts during rest, work and vasodilation are now attributed to precapillary sphincter action. /2/ Counts are averages. Assumed capillary length = 1 mm. Actual capillary length <0.5 mm. /3/ Based on RBC diameter, excluding Items 11-15, 37-38, 40-41, 43-47./4/ Capillary capacities determined by pressure injection are maximal, and differ from capacities (all vessels) by isotope and spectrophotometric methods, which may be minimal and indicate effective in vivo capacities. E.g., vascular capacities (cu mm/cu mm), assuming that muscle density = 1.0: skeletal muscle of cat, 0.027; dog, 0.018; rat, 0.004; cardiac muscle of cat, 0.084; dog, 0.046; rat, 0.042. From microtermy in hamster cheek pouch, in vivo compared with injected, effective capillary capacity/maximum capacity = 1/6. /5/ Calculated, excluding Items 28-34, 40-42, 45-47. /6/ By both hydrodynamic and injection methods, mammalian capillary surface area = 7.0 cu mm/cu mm, assuming that muscle density = 1.0. /7/ Muscle or animal stimulated before injection. /8/ Classified as working (W) on basis of habitual use. /9/ Low values for RBC diameter may be caused by shrinkage upon fixation.

Part II: CARDIAC MUSCLE

A = atrophied; H = hypertrophied; T = trained; U = untrained.

	Animal	Heart Area		Capillaries per sq mm Cross-section[1]	Capillaries per Fiber	Capillary Diameter[3] μ	Capillary Capacity[1, 3, 4] cu mm/cu mm	Capillary Surface Area[1, 4] sq mm/cu mm
1	Man, 5.9 yr			3744	0.3	8.4	0.207	98.8
2	49.8 yr			3343	0.8	8.4	0.185	88.2
3	51.0 yr		H	2483	0.8	8.4	0.138	65.5
4	63.3 yr		A	4613	0.6	8.4	0.256	121.7
5	Guinea pig			1970		7.5	0.087	46.4
6			U	1748		7.5	0.086	45.9
7			T	2819		7.5	0.125	66.4
8				3407		7.5	0.151	80.3
9			H	2950		7.5	0.130	69.5
10	Rabbit	Left ventricle		3420	1.1	7.5	0.151	80.6
11			H	2670	1.2	7.5	0.118	62.9
12		Right ventricle		3310	1.0	7.5	0.146	78.0
13			H	2740	1.2	7.5	0.121	64.6
14		Papillary		3230		5.0	0.063	50.7
15	Snake (Tropidonotus natrix)	Inner		900		14.5[5]	0.083	22.8
16		Periphery		1000	14.5[5]	14.5[5]	0.165	45.6

/1/ See Fn 2, Part I. /2/ Based on RBC diameter, excluding Item 14. /3/ See Fn 4, Part I. /4/ Calculated, excluding Item 14. /5/ Based on RBC dimensions of Natrix sp, 18.3 x 14.4 μ.

Circulation time is the time required for an indicator substance introduced into the blood stream to traverse the normal vascular path from a specified point, usually the point of introduction (as the antecubital vein in the arm), and to arrive at another point or area in sufficient concentration to register its arrival in some characteristic and recognizable manner. Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

	Species	Circuit	Registration Time sec	Indicator
1	Man	Arm to heart, left ventricle	8(6-9)	Diodrast
2	Adult	Arm to heart, right atrium	3.6(1.6-10)	Acetylcholine
3		Arm to lung	6.6(3.5-8)	Ether
4			6(3-9)	Paraldehyde
5		Arm to carotid sinus	11(3-24)	Lobeline
6			9.5(8-11)	a-Lobeline
7			15.6(9-21)	Sodium cyanide[1]
8		Arm to lips	17.5(15-20)	Fluorescein[2]
9		Arm to mouth	12(9-15)	Calcium chloride
10		Arm to face	21.5(13-30)	Histamine
11		Arm to tongue	12(9-15)	Calcium chloride
12			13.3(10-16)	Calcium gluconate
13			14.4(8-20)	Decholin
14			15(5-24)	Macasol[3]
15			12.4(7-17.8)	Magnesium sulfate
16			11.6(9-16)	Saccharin
17		Arm to tongue and nose	8.5(5-13)	Thiamine
18		Arm to throat	18(12-25)	Calcium gluconate
19			14(7-22)	Macasol[3]
20			14(11-17)	Magnesium sulfate
21		Arm to conjunctiva	10.6(7-16)	Fluorescein
22		Arm to ear	12.5(9-16)	Methylene blue[4]
23			14(10-21)	Dye[T-1824][5]
24		Arm to respiratory center	15(12-19)	Aminophylline
25			21(15-27)	Papaverine
26		Arm to arm	23(18-30)	Fluorescein
27			17.5(12-23)	Radium-C
28			19(14.5-26.2)	Riboflavine
29			19(10-20)	Thorium-X
30		Arm to opposite hand	25.5(23-28)	Fluorescein
31			27(26-28)	Macasol[3]
32		Arm to foot, open wound	23	Fluorescein
33		Arm to foot, intact skin	35(34-36)	Fluorescein
34			32.5(28-37)	Macasol[3]
35		Arm to perineum	26	Macasol[3]
36		Arm to rectum	18	Fluorescein
37		Right to left heart (lesser)	6.5	Radium-C
38		Through heart	1	Radium-C
39		Lung to face	19.5(14-25)	Amyl nitrite
40		Lung to medulla	7(5-10)	Carbon dioxide
41		Lung to ear	5.2(4-7)	Nitrogen, 100%[6]
42		Lung to opposite lung	(10-15)	Acetylene
43		Foot to tongue	41(22-75)	Histamine
44		Foot to groin	18(6-49)	Radioactive sodium
45		Foot to carotid sinus	33(27-39)	Sodium cyanide
46		Portal circ., rectum to lung	(11-25)	Ether
47		Total circulation	8(7-9)	Radioactive phosphorus[7]
48	Children	Arm to carotid sinus	10.6(9-14.5)	Sodium cyanide
49		Arm to tongue or nose	6(4-8)	Thiamine
50		Arm to opposite arm	11(5-17)	Radioactive sodium
51			8.9	Riboflavine
52	Newborn	Arm to conjunctiva	(5-14)	Fluorescein
53		Umbilical vein to lip	(3.1-7)	Fluorescein
54		Ductus venosus to lip	(3.3-6)	Fluorescein
55		Umbilical vein to umbilical vein	(30-60)	Congo red

	Species	Circuit	Registration Time sec	Indicator
56	Cat	Left common carotid art. to right auricle	6(3-9.5)	Radium-C
57		Femoral vein to carotid artery	3.2(3-3.5)	Conductivity
58			4(3-5)	Radioactive phosphorus[7]
59		Femoral artery to carotid artery	10(9-11)	Radioactive phosphorus[7]
60		Femoral artery to femoral vein	6(4-8)	Radioactive phosphorus[7]
61	Chicken	Sciatic vein to systemic arterioles	3	Acetylcholine
62	Cow	Mammary vein to opposite mammary vein	52	Fluorescein
63	Dog	Root of aorta to sino-atrial node	1.3(1.1-1.7)	Acetylcholine
64		Apex left ventricle to a-a node	1.8(1.7-2.1)	Acetylcholine
65		2-3 cm above root of aorta to a-a node	3.4(2.6-4.3)	Acetylcholine
66		Main pulmonary artery to a-a node	5.2(3.9-7.6)	Acetylcholine
67		Right ventricle to a-a node	6(4.4-8.8)	Acetylcholine
68		Leg vein to a-a node	6.7(4.0-9.5)	Acetylcholine
69		Superior vena cava to a-a node	6.7(6.4-9.9)	Acetylcholine
70		Femoral vein to right atrium	17(16-18)	Bismuth oil
71		Systemic (greater circulation)	5.3(3.5-7.1)	Conductivity
72		Pulmonary (lesser circulation)	5.8(4.0-7.6)	Conductivity
73		Right to left ext. jugular vein	9.25	Conductivity
74		Complete circulation	10.8(8.9-12.8)	Conductivity
75		Femoral vein to conjunctiva	12.6	Fluorescein
76		Right to left jugular vein	7.9(4.9-10.2)	Hexamethylene tetramine
77		Right to left ext. jugular vein	7.8	Lithium acetate
78		Right to left jugular vein	7.8(4.9-10.2)	Lithium benzoate
79		Femoral vein to carotid artery	7(6-8)	Radioactive phosphorus
80		Jugular vein to right heart	1.7(1-2.5)	Shadacol[9]
81		Right to left heart	5.5	Shadacol[9]
82		Left to right heart	6.0	Shadacol[9]
83		Femoral vein to carotid sinus	8.0	Sodium cyanide
84		Ext. jugular vein to carotid sinus	(9-13)	Sodium cyanide
85		Left ventricle or aorta to femoral artery	4.0	Sodium sulfocyanide
86		Complete circulation	10.5(10-11)	Sodium sulfocyanide
87	Goat	Pulmonary circulation, fetal	4.7	Iodine
88		Pulmonary circulation, birth	2.7	Iodine
89	Horse	Jugular vein to opposite jugular vein	22.5(20-25)	Potassium ferrocyanide
90	Sheep	Pulmonary circulation, fetal	2.7	Iodine
91	(lamb)	Pulmonary circulation, birth	1.4	Iodine
92		Complete circulation	(5-8)	Iodine
93	Rabbit	Pulmonary circulation	2.85	Conductivity
94		Crural artery to crural vein	3.8	Conductivity
95		Hepatic portal circulation	5.4(3.85-6.95)	Conductivity
96		Renal circulation	8	Conductivity
97		Jugular vein to crural vein	8.4	Conductivity
98		Complete circulation	10.5	Conductivity
99		Ear vein to eye	5.5(5-6)	Fluorescein
100		Right to left ear vein	4.8(3.4-7.2)	Hexamethylene tetramine
101			4.7	Lithium acetate
102			4.5(3.5-5.8)	Lithium chloride
103			6.0	Methylene blue[4]
104		Ear vein to medulla	4(3.3-5.2)	Sodium cyanide
105		Ear vein to carotid sinus	3.9	Sodium cyanide
106		Right jugular vein to right carotid art.	(2.4-3.4)	Sodium chloride
107		Left jugular vein to right femoral art.	(3.85-4.0)	Sodium chloride
108		Left to right jugular vein	(4.1-6.1)	Sodium chloride
109		Left jugular vein to right renal artery	(3.8-5.4)	Sodium chloride
110		Left jugular vein to right renal vein	(10.8-12.7)	Sodium chloride

/1/ Warm subject, 18.5; cold subject, 32.3. /2/ During exercise, 6-14 days to 5.9 yr; 10.4 for ages 6-12.9 yr. /3/ Magnesium sulfate compound. /4/ Photoelectric method. /5/ Photocell. /6/ With oximeter. /7/ Labelled cells. /8/ For ages

/9/ Iodophthalein sodium.

ant.=anterior; ext.=external; inf.=inferior; int.=internal; lt.=left; mid.=middle; post.=posterior; rt.=right; sup.=superior; trans.=transverse.

Part I: ARTERIES

Listed arteries represent important blood pathways. A complete atlas is not intended and branches of main arteries, so many cases, are not shown.

	Artery	Origin	Distribution
1	Alveolar, inferior	Internal maxillary	Lower teeth, gums, mandible, lower lip, chin.
2	Superior, anterior	Infraorbital	Incisors, canines of upper jaw.
3	Superior, posterior	Internal maxillary	Molars, bicuspids of upper jaw; maxillary sinus.
4	Aorta, abdominal	Thoracic aorta	Abdominal viscera, wall; pelvis; lower limbs.
5	Ascending, arch	Left ventricle	Heart muscle, head, neck, upper limbs.
6	Thoracic	Aortic arch	Thoracic wall, mediastinal structures.
7	Appendicular	Ileocolic	Mesentery of vermiform appendix.
8	Arcuate (renal)	Interlobar	Kidney parenchyma.
9	Auditory, internal	Anterior inf. cerebellar	Internal ear.
10	Auricular, anterior	Superficial temporal	Lat. surface auricle, external meatus.
11	Auricular, posterior	External carotid, 5th branch	Middle ear, mastoid cells, auricle, parotid gland, digastric and other muscles.
12	Axillary	Subclavian	Upper extremity, axilla, chest, shoulder.
13	Basilar	Right and left vertebral	Brain stem, internal ear, cerebellum, posterior cerebrum.
14	Brachial	Axillary	Shoulder, arm, forearm, hand.
15	Superficial	Brachial or axillary	Radial, or radial and ulnar arteries.
16	Bronchial	Aorta or intercostal	Bronchi, lungs.
17	Carotid, common	Innominate, right; aortic arch, left	Origin of external and internal carotids.
18	External	Commoo carotid	Neck, face, skull.
19	Internal	Common carotid	Mid-ear, brain, pituitary, orbit, choroid plexus of lateral ventricle.
20	Celiac	Abdominal aorta	Esophagus, stomach, duodenum, spleen, pancreas, liver, gallbladder.
21	Central of retina	Ophthalmic	Retina.
22	Cerebellar, ant. inf.	Basilar	Lower anterior cerebellar cortex.
23	Posterior inferior	Vertebral	Lower cerebellum, medulla, choroid plexus 4th ventricle.
24	Superior	Basilar	Upper cerebellum, mid-brain, pineal body, choroid plexus 3rd ventricle.
25	Cerebral, anterior	Internal carotid	Frontal lobe, medial surface cerebrum, corpus callosum.
26	Middle	Internal carotid	Lateral surface cerebrum and basal ganglia.
27	Posterior	Basilar	Occipital, temporal lobes, basal ganglia, choroid plexus of lateral ventricle.
28	Cervical, ascending	Inferior thyroid	Neck muscles, vertebrae, spinal canal.
29	Deep	Costocervical	Deep muscles of back of neck; first intercostal space.
30	Transverse	Thyrocervical trunk	Posterior muscles of neck, interscapular region.
31	Choroid	Internal carotid	Choroid plexus of lateral ventricle, hippocampus fimbria.
32	Ciliary, ant., post.	Ophthalmic and lacrimal	Iris, conjunctiva, choroid.
33	Circumflex, femoral		
	Lateral	Profunda femoris	Hip joint, thigh muscles.
34	Medial	Profunda femoris	Hip joint, thigh muscles.
35	Iliac, deep	External iliac	Abdominal muscles.
36	Superficial	Femoral	Inguinal glands, skin of thigh and abdomen.
37	Colic, left	Inferior mesenteric	Descending colon.
38	Middle	Superior mesenteric	Transverse colon.
39	Right	Superior mesenteric	Ascending colon.
40	Collateral, ulnar	Brachial	Lower arm and elbow.
41	Communicating, ant.	Anterior cerebral	Anterior perforated substance.
42	Posterior	Internal carotid	Uncinate gyrus, thalamus.
43	Coronary, left	Left aortic sinus	Heart.
44	Right	Right aortic sinus	Heart.
45	Cystic	Hepatic	Gallbladder, under surface of liver.
46	Digital (of fingers)	Metacarpals	Fingers.
47	Digital (of toes)	Metatarsals	Toes.
48	Diploic	Pericranial, meningeal	Diploe of skull.
79	Innominate	Arch of aorta	Right side of head, neck, upper limb.
80	Intercostal	Int. mammary, thoracic	Thoracic walls, muscles, vertebrae.
81	Interlobar (renal)	Renal aorta	Kidney lobes.
82	Interosseous, anterior	Ulnar	Deep structures of forearm.
83	Lacrimal	Ophthalmic	Lacrimal gland, eye muscles, cheek, eyelids.
84	Laryngeal, inferior	Inferior thyroid	Larynx, upper trachea, esophagus.
85	Superior	Superior thyroid	Larynx, pharynx.
86	Lenticular	Middle cerebral	Lenticular nucleus.
87	Lingual	External carotid	Tongue, tonsil, sublingual gland, epiglottis.
88	Lumbar (4 pairs)	Abdominal aorta	Abdominal walls, vertebrae, lumbar muscles, renal capsule.
89	Mammary, interior	Subclavian	Anterior thoracic wall, mediastinal structures.
90	Maxillary, external	External carotid	Face, tonsil, palate, submaxillary gland.
91	Internal	External carotid	Both jaws, teeth, chewing muscles, ear, meninges, nose, nasal sinus, palate.
92	Median	Volar interosseous	Median nerve, muscles of front forearm.
93	Medullary (arteriolae rectae)	Arcuate of kidney	Renal pyramids.
94	Meningeal, anterior	Ophthalmic, interior carotid	Bones, dura mater of anterior cranial fossa.
95	Middle or great	Internal maxillary	Bones, dura mater of middle cranial fossa.
96	Posterior	Ascending pharyngeal	Bones, dura mater of posterior cranial fossa.
97	Mesenteric, inferior	Abdominal aorta	Lower half of colon, rectum.
98	Superior	Abdominal aorta	Small intestine, proximal half of colon.
99	Metacarpal, dorsal	Radial, ulnar, interosseous.	Hand and fingers, dorsal.
100	Metatarsal, dorsal	Dorsalis pedis	Foot and toes, dorsal.
101	Musculophrenic	Internal mammary	Diaphragm; abdominal, thoracic walls.
102	Obturator	Hypogastric	Pelvic muscles, hip joint, ant. thigh.
103	Occipital	External carotid	Scalp, neck muscles, post.
104	Ophthalmic	Internal carotid	Eye, orbit, adjacent facial structures.
105	Ovarian	Abdominal aorta	Ovary, ureter, uterus, uterine tube.
106	Palatine, ascending	External maxillary	Soft palate, tonsil, auditory tube.
107	Descending	Internal maxillary	Soft, hard palates; tonsil.
108	Pancreatic	Splenic	Pancreas.
109	Pancreaticoduodenal		
	Inferior	Superior mesenteric	Pancreas, duodenum.
110	Superior	Gastroduodenal	Pancreas, duodenum.
111	Penis, deep, dorsal.	Internal pudendal	Penis.
112	Perforating	Profunda femoris	Muscles of thigh.
113	Pericardiacophrenic	Internal mammary	Pericardium, diaphragm, pleura.
114	Perineal	Internal pudendal	Perineum, skin of external genitalia.
115	Peroneal	Posterior tibial	Outside and back ankle, deep calf muscles.
116	Phrenic, inferior	Aorta, abdominal	Diaphragm, suprarenal glands.
117	Plantar arch	Lateral plantar	Sole of foot, toes.
118	Pontine	Basilar	Pons, brachia pontis, trigeminal roots.
119	Popliteal	Femoral	Knee, post. leg.
120	Princeps pollicis	Radial	Thumb vestrally.
121	Profunda brachii	Brachial	Humerus, posterior arm structures.
122	Profunda femoris	Femoral	Thigh muscles, hip joint.
123	Pudendal, external	Femoral	External genitalia, medial thigh muscles.
124	Internal	Hypogastric	Perineum, anal canal, external genitalia.
125	Pulmonary	Right ventricle	Lungs.
126	Radial	Brachial	Forearm, wrist, hand.
127	Renal	Abdominal aorta	Kidney.
128	Sacral, lateral	Hypogastric	Structures about coccyx and sacrum.
129	Middle	Aorta	Sacrum and coccyx.
130	Scapular, trans.	Thyreocervical	Clavicle, scapula, shoulder muscles, joint.
131	Scrotal, anterior	External pudendal	Anterior part of scrotum.
132	Posterior	Perineal	Posterior part of scrotum.

49	Dorsalis pedis	Anterior tibial	Dorsum of foot, toes.	133	Septal (nasal)	Sphenopalatine	Mucous membrane of nasal septum, palate.
50	Epigastric, inferior	External iliac	Abdominal muscles, cremaster, peritoneum.	134	Sigmoid	Inferior mesenteric	Sigmoid flexure of colon.
51	Superficial	Femoral	Skin of abdomen, superficial fascia.	135	Spermatic, internal	Abdominal aorta	Testis.
52	Superior	Internal mammary	Abdominal muscles, diaphragm.	136	Sphenopalatine	Internal maxillary	Interior of nose and nasal sinus
53	Esophageal	Gastric, inferior thyroid, left phrenic, thoracic	Esophagus.	137	Spinal, ant., post.	Intercostal, lumbar	Spinal cord.
				138	Splenic	Celiac	Splem, pancreas, stomach, greater omentum.
54	Ethmoidal anterior	Ophthalmic [aorta.	Dura mater, nose, frootal sinus, ant. and mid. ethmoidal cells.	139	Stapedial	Stylomastoid	Stapedius muscle.
				140	Stylomastoid	Posterior auricular	Tympanic cavity walls, mastoid cells, semicircular canals.
55	Posterior	Ophthalmic	Posterior ethmoidal cells, nose, dura mater.				
56	Femoral	External iliac	Lower abdominal wall, ext. genitalia, lower limb.	141	Subclavian	Innominate (right side), aortic arch (left side)	Neck, thoracic wall, spinal cord, brain, meninges, upper limbs.
57	Deep	Femoral	Thigh muscles, hip joint.				
58	Frontal	Ophthalmic	Anterior scalp.	142	Subcostal	Thoracic aorta	Region below 12th rib in abdominal wall.
59	Gastric, left	Celiac	Esophagus, lesser curvature of stomach.	143	Submental	External maxillary	Tissues under chio.
60	Right	Hepatic	Lesser curvature of stomach.	144	Subscapular	Axillary	Back of axilla, shoulder and scapular muscles.
61	Short	Splenic	Left portion greater curvature of stomach.	145	Supra-orbital	Ophthalmic	Forehead, upper muscles of orbit.
62	Gastroduodenal	Hepatic	Stomach, duodenum, pancreas.	146	Suprarenal, inferior	Renal	Suprarenal gland.
63	Gastroepiploic, left	Splenic	Stomach, greater omentum.	147	Middle	Aorta	Suprarenal gland.
	Right	Gastroduodenal	Stomach, greater omentum.	148	Superior	Inferior phrenic	Suprarenal gland.
65	Gluteal	Hypogastric	Hip joint, gluteal region.	149	Temporal, superficial	Exterior carotid	Parotid, auricle, scalp.
66	Hemorrhoidal, sup.	Inferior mesenteric	Upper part of rectum.	150	Thymic	Internal mammary	Mediastinum, thymus.
67	Middle	Hypogastric	Middle portion of rectum.	151	Thyroid, inferior	Thyreocervical trunk	Larynx, esophagus, trachea, neck muscles, thyroid.
68	Inferior	Internal pudendal	Anal canal.				
69	Hepatic	Celiac	Stomach, pancreas, duodenum, liver.	152	Superior	External carotid	Hyoid muscles, larynx, thyroid, pharynx.
70	Left	Hepatic	Left lobe of liver.	153	Thyreoides ima	Aortic arch, innominate	Thyroid gland.
71	Right	Hepatic	Right lobe of liver.	154	Tibial, anterial	Popliteal	Leg, ankle, foot, dorsal.
72	Hypophyseal	Internal carotid	Hypophysis.	155	Posterior	Popliteal	Leg, sole of foot, heel.
73	Intestinal	Superior mesenteric	Ileum, jejunum.	156	Tonsillar	Ascending palatine	Tonsil, neighboring tissues
74	Ileo-colic	Superior mesenteric	Cecum, appendix, ascending colon.	157	Tympanic	Int.maxillary, ext.carotid	Tympanic cavity.
75	Iliac, common	Abdominal aorta	Pelvis, abdominal wall, lower limb.	158	Ulnar	Brachial	Forearm, wrist, hand.
76	Int. and ext.	Common iliac	Abdominal wall, external genitals, lower limb.	159	Uterine	Hypogastric	Uterus, vagina, fallopian tube, round ligament.
77	Iliolumbar	Posterior hypogastric	Pelvic muscles, bones; 5th lumbar segment.	160	Vaginal	Hypogastric, uterine	Vagina, base of bladder, rectum.
78	Infra-orbital	Internal maxillary	Maxilla, maxillary sinus, upper teeth, lower lid, cheek, side of nose.	161	Vertebral	Subclavian	Neck muscles, vertebrae, spinal cord, brain, cerebellum, interior of cerebrum.

Part II: VEINS

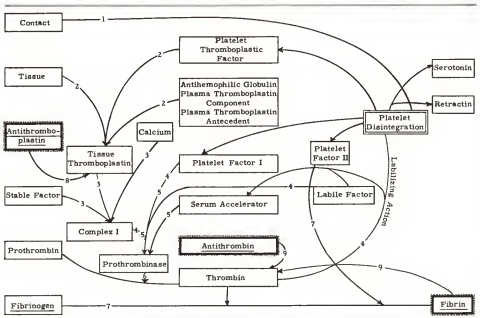
Veins, venous sinuses and plexuses having no accompanying artery of the same name, or differing considerably from the accompanying artery, are listed. Veins having tributaries with the same distribution and name as the accompanying arteries are not shown.

	Vein	Location	Drains into:		Vein	Location	Drains into:
1	Accessory hemiazygos	Lt. side of vertebral column.[1]	Either azygos or hemiazygos.	24	Parumbilical	Round ligament of liver.	Portal.
2	Anterior facial	Anterior face.	With post., forms common facial.	25	Portal	Lesser omentum.	Sinusoids of liver.
3	Anterior jugular	Near midline of neck.	Ext. jugular or subclavian.	26	Prostatic plexus	Fascial sheath of prostate.	Pudendal and vesical plexuses.
4	Azygos	Rt. side of vertebral column.[1]	Superior vena cava.	27	Pterygoid plexus	Between pterygoid muscles.	Internal maxillary.
5	Basilic	Medial side of arm.	Joins brachial to form axillary.	28	Pudendal plexus	Behind symphysis pubis, in front of bladder.	Vesical and hypogastric veins.
6	Cavernous sinus	Middle cranial fossa.	Int. jugular via sup. petrosal sinus.				
7	Cephalic	Lateral side of arm.	Axillary.	29	Pyloric	Lesser curvature of stomach.	Portal.
8	Common facial	Below angle of mandible.	Internal jugular.	30	Sigmoid sinus	Groove on internal surface of temporal bone on petrous and mastoid parts.	Internal jugular.
9	Coronary sinus of heart	Post. part coronary sulcus.	Right atrium.				
10	Coronary of stomach	Lesser curvature of stomach.	Portal.				
11	Emissary	Various apertures of skull.	Intracranial venous sinuses, connecting with veins external to skull.	31	Small saphenous	Back of leg.	Popliteal.
				32	Straight sinus	Junctioo of falx cerebri with tentorium cerebelli.	Transverse sinus.
12	External jugular	Side of neck, superficial.	Subclavian.				
13	Great cardiac	Ant.longitudinal sulcus of heart.	Coronary sinus.	33	Sup. sagittal sinus	Attached margin falx cerebri.	Confluence of sinuses or transverse sinus.
14	Great cerebral	Below and behind splenium of corpus calloseum.	Straight sinus.				
				34	Sup. vena cava	Behind first and second intercostal spaces and right margin of sternum.	Right atrium.
15	Hemiazygos	Lt. side of vertebral column.[1]	Azygos.				
16	Hemorrhoidal plexus	Rectum.	Sup., mid., inf. hemorrhoidal veins.				
17	Hepatic	Posterior surface liver.	Inferior vena cava.	35	Trans. sious	Attached margin tentorium cerebelli.	Internal jugular via sigmoid sinus.
18	Inf. petrosal sinus	Inferior petrosal sulcus of skull.	Interoal jugular.				
19	Inf. sagittal sinus	Lower edge of falx cerebri.	Straight sinus.	36	Vertebral plexus	Within vertebral canal (internal) and around vertebrae (external).	Intracranial venous sinus, segmental tributaries of various parietal and visceral veins.
20	Inf. vena cava	Front of lumbar vertebral column, right of aorta.	Right atrium.				
21	Innominate	Root of neck.	Superior vena cava.	37	Vesical plexus	Lower bladder, base prostate gland.	Hypogastric.
22	Internal jugular	Side of neck.	Innominate.				
23	Oblique of left atrium	Back of left atrium.	Coronary sinus.	38	Vorticose	Eyeball.	Ciliary, ophthalmic veins.

[1] In thorax.

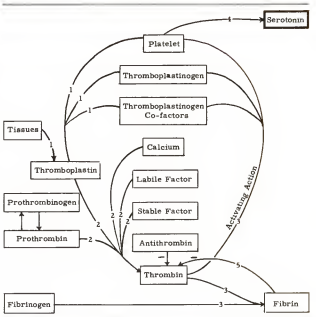
At the present time the concept of blood coagulation is more uncertain than it was before discovery of the newer clotting factors. It must be recognized that these charts are merely guides and will require modification as new data become available.

Part I: THEORY OF M. STEFANINI



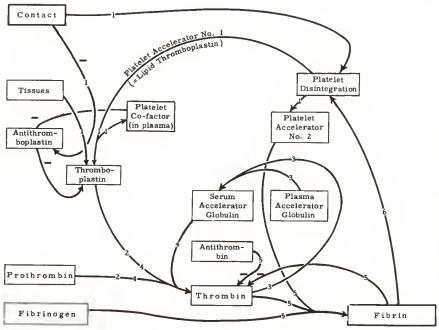
/1/ Contact with foreign surface (wounded vessel wall) causes disintegration of platelets. This is followed by the liberation of a number of agents present in or carried by platelets: serotonin (factor of vascular contractility), retractin (clot retraction agent), thromboplastic factor, platelet factors I and II. There is increasing evidence that platelet factor I is only a labile factor absorbed on platelets. Evidence for platelet factor II is somewhat meager and this factor might be disregarded in future theories. /2/ Platelet thromboplastin factor interacts with a number of plasma factors (antihemophilic globulin, plasma thromboplastin component, plasma thromboplastic antecedent, possibly others) to form the equivalent of tissue thromboplastin. This, of course, may be supplied directly from tissue. /3/ Tissue thromboplastin, calcium and stable factor (proconvertin, factor VII, etc.) interact to form an intermediary complex (convertin). /4/ The intermediary complex (complex I) reacts with the labile factor (proaccelerin, factor V) to form a new agent (prothrombinase). Some prothrombin is then converted to thrombin and this initiates the "autocatalytic phase" of blood coagulation. Thrombin then determines further disintegration of platelets and also conversion of the labile factor to a more active accelerator of the conversion of prothrombin, the serum accelerator (accelerin). /5/ As result of the autocatalytic reaction, the formation of prothrombinase proceeds at an even more accelerated speed. A factor liberated from platelets (factor I) takes part in this reaction. /6/ Prothrombinase, formed in large quantities, converts almost completely prothrombin to thrombin. /7/ Thrombin converts fibrinogen to fibrin. A platelet factor (factor II) and a hypothetical plasma factor (not shown in the diagram) accelerate the formation of fibrin. /8/ Inhibitors exist for each phase and each blood coagulation factor. Antithromboplastin is a well documented one and antagonizes the activity of tissue thromboplastin. /9/ The conversion of fibrinogen to fibrin is also antagonized by two factors: a plasma antithrombin and the fibrin clot itself, through its property of adsorbing thrombin.

Part II: THEORY OF A. J. QUICK



/1/ Thromboplastin is (a) released by injured tissue and is (b) formed in the blood by the interaction of a platelet factor, thromboplastinogen (antihemophilic factor), and one or more co-factors (PTC, PTA, etc.) through the activating action of thrombin. /2/ Thromboplastin, prothrombin, calcium and labile factor interact stoichiometrically and, in addition, stable factor is needed to form thrombin. In adult human blood a large fraction of the prothrombin is in an inactive state: prothrombinogen (probably as a prothrombin inhibitor complex). During storage or clotting all prothrombinogen becomes activated. /3/ The thrombin formed not only converts fibrinogen to fibrin but participates in the activation of plasma factors (probably thromboplastinogen or one of its co-factors), thereby bringing about lysis of platelets and initiating a chain reaction. /4/ The platelets release a vasoconstrictor, serotonin, through the action of thrombin, which probably functions in local hemostasis. /5/ The prompt removal of thrombin by fibrin holds in check the autocatalytic reaction mediated through the action of thrombin on platelets, thromboplastinogen and its co-factors.

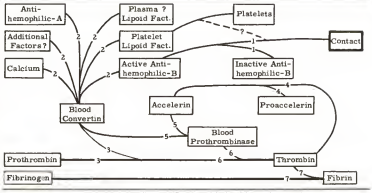
Part III: THEORY OF L. M. TOCANTINS



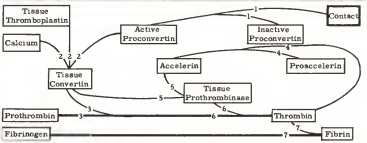
/1/ Contact of the blood with certain surfaces (damaged blood vessel endothelium, glass) initiates the first changes which lead to the inception of clotting; blood platelets agglutinate, adhere to the surface and/or disintegrate, releasing (a) cephalin like accelerator and (b) fibrinoplastic factor (platelet accelerator No. 2). There is dissociation of the platelet co-factor/lipid inhibitor complex, with freeing of the platelet co-factor. The latter conjugates with the platelet lipid accelerator and forms plasma thromboplastin. Some of the thromboplastin of the blood is offset or neutralized by the antithromboplastin; some of the antithromboplastin is itself adsorbed or neutralized at the contacting surface. /2/ Thromboplastin (from tissues and/or platelets) brings about a minimal conversion of prothrombin to thrombin. /3/ This initially formed thrombin activates the accelerator system, that is, the conversion of inactive plasma accelerator globulin to active serum accelerator globulin. /4/ Thromboplastin together with serum accelerator globulin causes acceleration of the conversion of prothrombin to thrombin. /5/ Some of the thrombin may be inactivated by antithrombin. The thrombin that escapes such inactivation acts, with the aid of platelet accelerator No 2, to cause the conversion of fibrinogen to fibrin. Some of the excess thrombin is removed from the plasma by adsorption on fibrin. /6/ Fibrin probably causes further disintegration of platelets.

Part IV: THEORY OF P. A. OWREN

Section 1: THE INTRINSIC BLOOD COAGULATION SYSTEM



Section 2. THE EXTRINSIC (TISSUE-BLOOD) COAGULATION SYSTEM



(1) The intrinsic blood coagulation system: /1/ Contact activates the inactive antihemophilic B factor. (Plasma thromboplastin component, Christmas factor.) /2/ Reactions take place between plasma thromboplastin factors (antihemophilic A-factor (A.H.G.) and active antihemophilic B factor), lipoid factors with cephalin-like activity (from platelets and possibly also in plasma) and calcium to form an intermediate complex termed blood convertin. This reaction possibly requires one or more additional factors such as: plasma thromboplastin antecedent, the IV thromboplastic factor, factor X, Prower factor. The problems of platelet disintegration and the significance of contact influence on platelets are still unsolved. /3/ Blood convertin brings about a minimal conversion of prothrombin to thrombin. /4/ This initially formed thrombin starts the accelerator system, i.e., the conversion of proaccelerin to accelerin. /5/ Blood convertin and accelerin interact in the presence of calcium to form blood prothrombinase. /6/ Blood prothrombinase produces rapid conversion of prothrombin to thrombin. /7/ Thrombin is now formed in sufficient quantity to convert fibrinogen to fibrin. NB: Proconvertin does not take part in the intrinsic blood coagulation system.

(2) The extrinsic (tissue-blood) coagulation system: /1/ Contact activates inactive proconvertin to active proconvertin. /2/ Tissue thromboplastin (liberated by tissue injury), active proconvertin and calcium interact to form tissue convertin. /3/ Tissue convertin brings about a minimal conversion of prothrombin to thrombin. /4/ This initially formed thrombin starts the accelerator system, i.e., the conversion of proaccelerin to accelerin. /5/ Tissue convertin and accelerin interact in the presence of calcium to form tissue prothrombinase. /6/ Tissue prothrombinase produces rapid conversion of prothrombin to thrombin. /7/ Thrombin is now formed in sufficient quantity to convert fibrinogen to fibrin. NB: Platelets and antihemophilic factors do not take part in the extrinsic blood coagulation system.

(CIC = cardio-inhibitor center; CAC = cardio-accelerator center; VCC = vasoconstrictor center; N = nerve; NN = nerves.

	Reflex	Effective Stimulus	Reflex Pathway: Receptor	Reflex Pathway: Afferent	Reflex Pathway: Center	Reflex Pathway: Efferent	Response	Species[1]	Conditions in which Reflex is Increased
1	Veno-cardiac (Bainbridge)	Blood pressure ↗ in great veins, R auricle.	Walls of great veins entering R auricle; wall of R auricle(?).	Vagus N (afferent fibers).	CIC ↘ CAC ↗	Vagus N; sympathetic(?).	Heart rate ↗.	Man, dog(?)[2]	Exercise; inspiration; R ventricular failure.
2	Veno-arterial (McDowall)	Blood pressure ↘ in great veins,					General arterial vasoconstriction retarda ↘ in arterial blood pressure.	Man	Hemorrhage; erect posture.
3		Blood pressure ↗ in great veins, R auricle.			VCC ↗	Sympathetic NN.	General arterial vasoconstriction; arterial blood pressure ↗.	Dog, cat	Exercise.
4	Pulmonary vaso-cardiac[3]	Pulmonary blood pressure ↗; distension lung vessels.	Pulmonary arteries(?);VV(?); capillaries(?),	Vagus N (afferent fibers).	CIC ↘ CAC ↗	Vagus N.	Heart rate ↗.	Man	Exercise; L. ventricular, L auricular failure.
5	Pulmonary alveolo-cardiac[3]	"Collapse of lung alveoli."	Pulmonary alveoli.		CIC ↘ CAC ↗	Vagus N; sympathetic(?).			Lung consolidation, collapse; extreme expiration.
6	Depressor Aorto-cardiac	Aortic pressure ↗ [4].	Wall of aortic arch.	Vagus N (afferent fibers).	CAC ↘ CIC ↗	Vagus N; sympathetic NN(?).	Heart rate ↘.	Man, rabbit	Exercise; recumbent posture or lowered head; hypertension.
7	Aorto-arterial				VCC ↘		Vasodilatation; arterial and venous blood pressure ↘; syncope.		
8	Carotid sinus: Cardiac	Carotid blood pressure ↗ [4]; direct pressure on sinus.	Adventitia of carotid sinus.	Glosso-pharyn-geal N; vagus N[5].	CIC ↗ CAC ↘	Vagus N; sympathetic(?).	Heart rate ↘.	Man	Exercise; recumbent posture or lowered head; pressure on neck.
9	Arterial				VCC ↘	Sympathetic.	Vasodilatation; arterial and venous blood pressure ↘; syncope[6].		
10	Aortic & carotid body: Cardiac	Arterial blood O_2 ↘; blood free CO_2 ↗; blood pH ↘.	Carotid-aortic body chemo-receptors.		CAC ↗ CIC ↘		Heart rate ↗.	Man	Acetylcholine; acidosis; anemia; asphyxia; deep anesthesia.
11	Arterial				VCC ↗		Blood pressure ↗; vasoconstriction.		
12	Antigravity vascular reflexes[7]	Pressure & voluntary changes associated with erect posture.	Brain(?); pacinian corpuscles(?).	Multiple(?).	CIC ↘ VCC ↗	Sympathetic NN.	Heart rate ↗; splanchnic vasoconstriction; venous tone ↗.	Man	Assumption of erect posture.
13	Myo-arterial (Loven)	Muscular contraction.	Receptors among fibers of skeletal muscle.	Afferent fibers in "motor" nerve trunks.	VCC ↗ (local↘)	Vasodilatation NN; sensory NN.	Local vasodilatation; remote vasoconstriction; blood pressure ↗.	Man(?), dog	Muscular activity.
14	Myo-cardiac	Anoxic muscular activity.			CIC ↘	Vagus N.	Heart rate ↗.	Man	Arterial compression; arterial obstruction (thrombosis, endarteritis).
15	Myo-arterial (Alam and Smirk)				VCC ↗ (local↘)	Sympathetic; vasodilatation NN.	Blood pressure ↗.		
16	Pain N fibers: cardiac,	Strong stimulated pain fibers; stimulated splanchnics.			CIC ↗ VCC ↘		Heart rate ↘; splanchnic vasodilatation; blood pressure ↘.	Man	Blow to jaw, epigastrium; painful injury or disease, e.g. colic.
17	arterial								
18	Cold N fibers	Stimulation of skin cold receptors.		Cutaneous.	VCC ↗	Cutaneous, sensory.	Cutaneous vasoconstriction.	Man	Exposure to cold.
19	Thermo-arterial	Stimulation of skin heat receptors.		sensory NN	VCC ↘	Sympathetic.	Cutaneous vasodilatation[8].	Man	Exposure to heat.
20	Medullary cardio-inhibitor center (CIC) (vagus)	Reflex inhibition, cf. 1, 4, 5, 10, 12, 14.	CIC		CIC ↘ CAC ↗	Vagus N; sympathetic NN.	Heart rate ↗.	Man	Exercise; L or R heart failure; shock; erect posture.
21		Arterial blood free CO_2 ↗, O_2 ↘, pH ↘.							Exercise; anemia; acetylcholine; asphyxia; acidosis.
22		Blood temperature ↗.							Pyrexia.
23		Higher center inhibition (hypothalamus).							Emotion[9]; fear, anxiety. (usual response).
24		Higher center stimulation (hypothalamus).			CIC ↗ CAC ↘		Heart rate ↘; syncope or faintness ("vasovagal attack").		Emotion[9]; disgust; anxiety. fear (less frequent response).
25		Blood flow ↘.							Cerebral compression; tumor.
26		Reflex stimulation, cf. 6, 8, 16.							Hypertension; blow to epigastrium.
27	Medullary vasoconstrictor center (VCC)	Reflex stimulation, cf. 2, 3, 11, 12, 13, 15, 18.	VCC		VCC ↗	Sympathetic NN.	Vasoconstriction; blood pressure ↗.	Man	Exercise; R heart failure; erect posture; shock; hemorrhage.
28		Arterial blood free CO_2 ↗, pH ↘.							Exercise; CO_2 inhalation; apnea.
29		Blood flow ↘.							Shock; hemorrhage; heart failure with ↘ output; tumor.
30		Higher center stimulation (hypothalamus, cortex).				Vagus N; sympathetic NN.	Splanchnic vasoconstriction; cutaneous vasodilatation or constriction; systolic blood pressure ↗.		Emotion[9]; excitement, anger, rage.
31		Higher center inhibition (hypothalamus).			VCC ↘	Vagus NN; sympathetic NN.	Splanchnic vasodilatation; blood pressure ↘; fainting.		Emotion[9]; fear, anger, rage.
32		Blood temperature ↗.					Cutaneous vasodilatation (flushing).		Fever.
33		Reflex inhibition, cf. 7, 9, 17.							Rise of blood pressure.

/1/ These reflexes have been demonstrated only in the forms listed, but may have wide mammalian distribution. /2/ Best seen in animals with marked tonic vagal inhibition of heart rate; not seen in frog, rabbit; slight in cat. /3/ May be the same as Hering-Breuer reflex by irradiation from respiratory center to CIC. /4/ ↘ blood pressure has opposite effects. /5/ For aortic sinus and body. /6/ When sinus is hyperactive. /7/ A depressor reflex (↘ blood pressure) from mesenteric vessels has been described for man, cat. /8/ Stimulation of heat receptors may actually cause vasoconstriction, the reflex vasodilatation resulting from removal of cold stimulus. /9/ Emotion is also associated with secretion of adrenalin.

Temperature coefficient of specific resistance: (a) $-2\%/^{\circ}C$ whenever frequency dependence is small; (b) complicated function of frequency, but always above $-2\%/^{\circ}C$ when frequency dependence is pronounced.
Temperature coefficient of dielectric constant: (a) Smaller than 0.5% when frequency dependence is small; (b) positive, but complicated function of frequency when frequency dependence is pronounced.

cps=cycles per second; kc=kilocycles per second; Mc=megacycles per second.

	Frequency	Muscle	Heart Muscle	Liver	Lung*	Spleen	Kidney	Brain	Fatty Tissue	Bone	Bone Marrow	Whole Blood	Plasma	0.9% NaCl
							Specific Resistance (ohm cm)							
1	10 cps			1220[1]								165[2]		
2	100 cps			1060[1]								165[2]	60[2]	
3		800[1]	750[1]	890[1]	1600[1]				1500-5000[1]			168[2]		
4	1 kc			970[1]	400-850[3]				1700-2500[3]			147[4]		
5			830-900[5]	1000-1600[5]	1400-1900[5]			500-800[5]				120-135[5]		
6		980[6]		700-1300[7]		260-430[7]		450-550[7]				130-180[8]		
7	10 kc	880[6]		850[1]								147[4]		
8				460[1]										
9	100 kc	170-250[9]	190-240[9]	220-550[9]	165-200[9]	250-500[9]	150-270[9]	460-850[9]				147[4]		
10				550-800[7]										
11		520[6]		420[10]										
12		160-210[9]	180-230[9]	210-420[9]	150-280[9]	230-360[9]	140-250[9]	430-700[9]				140[4]		
13	1 Mc			400-550[7]										
14		250[6]		400[10]										
15	10 Mc	150-170[9]	140-180[9]	180-260[9]	110-150[9]	150-170[9]	120-170[9]	300-450[9]				90[4]		
16				250[10]										
17		100-130[11]		120-145[11]	95-130[11]	85-105[11]	100-120[11]	160-230[11]	1170-1250[11]			82[12]	70[12]	
18	100 Mc	120-160[9]	130-170[9]	150-200[9]	100-140[9]	110-150[9]	100-150[9]	200-300[9]	1500[9]				61[11]	
19		140-200[13]		180-210[13]		150[13]	130-160[13]	220-260[13]	2200-4300[13]		4100-5300[13]	120-150[13]	80[13]	
20		120-150[13]		150-180[13]		120[13]	90-140[13]	180-200[13]	1700-2500[13]		3000-5000[13]	80-100[13]	60[13]	
21		75-794[14]		98-1061[14]					700-1400[14]	2000[14]	1000-2300[14]	64-72[14]	54[14]	49[14]
22	1000 Mc	81-84[15]	83-100[15]	92-100[15]	137[15]		81-82[15]		1100-3500[15]			80[15]		56[15]
23		77[16]		100[16]					2500[16]					
24		1214		15-17[14]					240-370[14]	150[14]	60-200[14]	11[14]	9[14]	9[14]
25	10,000 Mc	1317							210[17]	130[17]	100[17]	9, 6[17]		
26												9, 3[18]		
							Dielectric Constant (Relative to Vacuum)							
27	10 cps	2500x10[3][19]												
28	100 cps	800x10[3][19]	800x10[3][1]	900x10[3][1]	450x10[3][1]				150x10[3][1]					
29		1000x10[3][19]												
30	1 kc	130x10[3][19]	300x10[3][1]	150x10[3][1]	90x10[3][1]				50x10[3][1]					
31		170x10[3][19]										2900[4]		
32		100x10[3][6]												
33		50x10[3][1]	100x10[3][1]	50x10[3][1]	30x10[3][1]				20x10[3][1]					
34	10 kc	90x10[3][19]										2810[4]		
35		50x10[3][6]												
36	100 kc	30x10[3][19]		7,000-12,000[7]								2740[4]		
37		20x10[3][6]												
38	1 Mc	2x10[3][5]		1200-2000[7]								2040[4]		
39	10 Mc											2004		
40				65-75[14]					8-13[11]					
41	100 Mc	69-73[13]		72-74[13]		88-90[13]	83-84[13]	70-75[13]				72-74[13]	82[13]	
42		71-76[13]		76-79[13]		100-101[13]	87-92[13]	81-83[13]	11-13[13]		7-8[13]	73-76[13]	76[13]	
43		49-52[14]		46-47[14]					4, 3-7, 5[14]	8[14]	4, 3-7, 8[14]	58-62[14]	69[14]	72[14]
44	1000 Mc	53-55[15]	53-57[15]	44-52[15]	35[15]		53-56[15]		3, 2-6[15]			63[15]		78[15]
45		61[16]		50[16]					9, 5[16]					
46		40-42[14]		34-38[14]					3, 5-3, 9[14]	8[14]	4, 4-6, 6[14]	50-52[14]	61[14]	66[14]
47	10,000 Mc	29[17]							3, 6[17]	6, 6[17]	5, 8[17]	45[17]		
48												48[18]		

* Partially or totally deflated, except material described in Footnote 1.

/1/ Dog, material in situ at body temperature. /2/ Sheep, material at 18°C, except plasma at 37°C (Line 3). /3/ Dog, in situ at body temperature. /4/ Rabbit, at room temperature. /5/ Rabbit, excised material at 37°C. /6/ Rabbit, excised piece at room temperature. /7/ Man and various animals, excised pieces and minced material at 23°C. /8/ Sheep, 18°C. /9/ Man, minced material at 23°C. /10/ Rabbit, minced material at 23°C. /11/ Man, minced material at 37°C. /12/ Sheep, at 20°C. /13/ Beef and pork, excised material at 20°C (Lines 19, 41), and at 37°C (Lines 20, 42). /14/ Dog and horse, blood and excised tissues measured at 38°C, except bone and bone marrow at 25°C. /15/ Man, excised piece at 27°C. /16/ Beef, minced material at 22°C. /17/ Man, excised piece at 32°C. /18/ Man, excised material at 35°C. /19/ Frog, excised piece at 25°C.

Resting and action potential data are restricted to intracellular recording, unless otherwise noted. Values obtained with intracellular electrodes filled with 3M KCl are considered as corrected for junction potential. Values in parentheses are ranges. Space constant of fiber (λ) in paraffin oil = $\sqrt{r_m/(r_0+r_i)}$, in cm, where r_0 = resistance of outside fluid per unit length, in ohm-cm^{-1}; r_i = internal resistance of fiber per unit length, in ohm-cm^{-1}; and r_m = transverse resistance times unit length of fiber, in ohm-cm. Time constant of the membrane (τ) = $R_m \cdot C_m$, in msec, where R_m = D.C. resistance of fiber membrane, in ohm-cm^2, and C_m = membrane capacity = $\frac{\tau}{R_m}$ = $\frac{\tau}{r_m \cdot 2\pi a}$. R_m also = $r_m \cdot 2\pi a$ (where a= fiber radius). Specific resistance of internal protoplasm (R_i), in ohm-cm, = $r_i \cdot \pi a^2$. Specific resistance of outside fluid (R_o), in ohm-cm, has following values: Woods Hole sea water, 20.9 ohm-cm (25°C); Tyrode's solution, 51 ohm-cm (37°C); frog Ringer's, 94 ohm-cm (18°C), 92 ohm-cm (19°C), 90 ohm-cm (20°C), 83 ohm-cm (22°C); myelin sheath, sciatic nerve, 800 megohm-cm.

	Tissue and Property	Value
	Squid (Loligo forbesi)	
	Unmyelinated nerves[1]	
1	Fiber diameter, μ	500
2	Resting potential, observed, mV	50
3	Action potential, amplitude, mV	90
	Unmyelinated nerves[2]	
4	Fiber diameter, μ	500
5	Resting potential, observed, mV	45
6	After correction for junction potential, mV	60
7	Action potential, amplitude, mV	90
	Unmyelinated nerves[3]	
8	Fiber diameter, μ	500-700
9	Temperature, °C	20
10	Resting potential, observed, mV	48(40-53)
11	After correction for junction potential, mV	62
12	Action potential, amplitude, mV	88(82-89)
13	Maximum rate of rise, V·sec^{-1}	630
14	Maximum rate of fall, V·sec^{-1}	380
	Unmyelinated nerves[4]	
15	Fiber diameter, μ	500-700
16	Temperature, °C	20
17	Resting potential after correc. junct. pot., mV	47
18	Action potential, amplitude, mV	80
19	Maximum rate of rise, V·sec^{-1}	500
20	Maximum rate of fall, V·sec^{-1}	301
	Squid (Loligo pealei)	
	Unmyelinated nerves[5]	
21	Fiber diameter, μ	500
22	Resting potential, observed, mV	51(46-59)
23	After correction for junction potential, mV	61
24	Action potential, amplitude, mV	108(77-168)
	Unmyelinated nerves[6]	
25	Fiber diameter, μ	400
26	Temperature, °C	21-28
27	Resting potential after correc. junct. pot., mV	48.6(27.5-68)
28	Action potential, amplitude, mV	85.3(46-127)
29	Duration, msec	0.35-0.5[4], 4.5[5]
30	Conduction speed, m·sec^{-1}	19.2
	Unmyelinated nerves	
31	Fiber diameter, μ	500
32	Temperature, °C	10
33	Membrane capacity[6], μF·cm^{-2}	1.1
	Unmyelinated nerves	
34	Fiber diameter, μ	500
	Resistance[6]	
35	Specific; internal protoplasm, ohm-cm	71
36	Membrane capacity[6], μF·cm^{-2}	1.8
	Unmyelinated nerves	
37	Fiber diameter, μ	500
38	Temperature, °C	22-25
39	Space constant, mm	2.3(1.8-3.8)
40	In sea water, mm	6.0(5.0-9.3)
	Resistance[7]	
41	Specific; internal protoplasm, ohm·cm	29
42	D.C.; fiber membrane, ohm·sq cm	700[8](400-1100)
	Unmyelinated nerves	
43	Fiber diameter, μ	500
	Resistance[6]	
44	D.C.; fiber membrane, ohm·sq cm	<200
	Unmyelinated nerves	
45	Fiber diameter, μ	500
	Resistance[9]	
46	D.C.; fiber membrane, ohm·sq cm	23(14.4-40.5)
	Unmyelinated nerves	
47	Fiber diameter, μ	500
	Resistance[10]	
48	D.C.; fiber membrane, ohm·sq cm	350[11]
	Unmyelinated nerves	
49	Fiber diameter[12], μ	527; 463; 426
50	Temperature, °C	21-25
51	Conduction speed[12], m·sec^{-1}	34.8; 31.1; 29.2

	Tissue and Property	Value
	Cuttlefish (Sepia officinalis)	
	Unmyelinated nerves[2]	
52	Fiber diameter, μ	200
53	Temperature, °C	12-17
54	Resting potential after correc. junct. pot., mV	63(53-67)
55	Action potential[13], amplitude, mV	120
56	Duration, msec	1[4], 75
57	Maximum rate of rise, V·sec^{-1}	840(650-1150)
58	Conduction speed, m·sec^{-1}	6.7
	Unmyelinated nerves[2]	
59	Fiber diameter, μ	204(126-306)
60	Temperature, °C	12-17
61	Space constant[14], mm	5.7(2.0-10.3)
	Resistance[14]	
62	Specific; internal protoplasm, ohm-cm	63(34-105)
63	D.C.; fiber membrane, ohm-sq cm	9,200(1,400-31,700)
64	Membrane capacity[14], μF·cm^{-2}	1.17(0.46-3.76)
	Lobster (Homarus vulgaris)	
	Unmyelinated nerves	
65	Fiber diameter, μ	75
66	Resting potential, observed, mV	62
67	Action potential[13], amplitude, mV	106
	Unmyelinated nerves	
68	Fiber diameter, μ	75
69	Action potential[13], amplitude, mV	110
	Unmyelinated nerves	
70	Fiber diameter, δ, μ	75
71	Temperature, °C	15-20
72	Space constant[14], mm	1.61(0.81-2.95)
	Resistance[14]	
73	Specific; internal protoplasm, ohm-cm	60.5(43.2-83.6)
74	D.C.; fiber membrane, ohm-sq cm	2290(564-7330)
75	Membrane capacity[14], μF·cm^{-2}	1.3(0.46-3.24)
	Crab (Carcinus maenas)	
	Unmyelinated nerves	
76	Fiber diameter, μ	25-35
77	Space constant[14], mm	1.98(0.89-2.82)
	Resistance[14]	
78	Specific; internal protoplasm, ohm-cm	90.0(67.1-115.8)
79	D.C.; fiber membrane, ohm-sq cm	7,653(2,050-15,600)
80	Membrane capacity[14], μF·cm^{-2}	1.11(0.62-2.02)
81	Action potential[13], amplitude, mV	116
	Unmyelinated nerves	
82	Fiber diameter, μ	30
83	Resting potential, observed, mV	71-94
84	Action potential[13], amplitude, mV	116-153
	Unmyelinated nerves	
85	Fiber diameter, δ, μ	30
86	Temperature, °C	21
87	Conduction speed, m·sec^{-1}	3-4
	Crab (Carcinus maenas and Portunus depurator)	
	Extensor muscle, carpopodite[2]	
88	Fiber diameter, μ	100-600[15]
89		70-500[16]
90	Temperature, °C	20
91	Space coostant[17], mm	(0.4-2.65)
	Resistance[17]	
92	Specific; internal protoplasm, ohm-cm	69
93	D.C.; fiber membrane, ohm-sq cm	100(20-2000)
94	Membrane capacity[17], μF·cm^{-2}	40
95	Resting potential after correc. junct. pot., mV	70±0.5[18](56-93)
96	Action potential, amplitude, mV	61±1.2[18](0-84)[19]
97	Duration, msec	3.5(2-17)
98	Maximum rate of rise, V·sec^{-1}	20.5±1
99	Conduction speed, m·sec^{-1}	0.3
	Locust (Locusta migratoria migratoroides R. and F.) and Cockroach (Periplaneta americana L.)	
	Extensor tibialis muscle, metathoracic leg[2]	
100	Resting potential after correct. junct. pot., mV	60
101	Action potential amplitude, mV	60-75

/1/ Solution in internal electrode used to depolarize: sea-water. /2/ Solution in internal electrode used to depolarize: 3M KCl. /3/ Solution in internal electrode used to depolarize: isotonic KCl. /4/ Spike. /5/ Positive after-phase. /6/ Determined by alternating current and transverse electrodes. /7/ Resistance length measurements made with direct current. /8/ 1000 ohm-cm^2 adopted as best value. (Value for axons in better physiological condition.) /9/ Determined by direct current pulses and internal electrodes. /10/ Determined by alternating current and longitudinal electrodes. /11/ Assuming membrane capacity=1.1. /12/ Passing from the proximal to the distal end of the giant axon. /13/ Determined by external electrodes. /14/ Determined by direct current pulses and longitudinal electrodes. /15/ Carcinus maenas. /16/ Portunus depurator. /17/ Determined by square wave pulses and internal electrodes. /18/ Standard error of mean. /19/ Value of zero omitted in averaging.

	Tissues and Property	Values
	Locust (Locusta migratoria migratoriodes R. and F.) and Cockroach (Periplaneta americana L.) (concluded)	
102	Maximum rate of rise, V·sec^{-1}	17[20]
103		36[21]
104	End-plate potential, rate of rise, V·sec^{-1}	14[20]
105		34[21]
	Eel, electric (Electrophorus electricus L.)	
	Electroplates[6]	
106	Fiber diameter[22], μ	100
107	Temperature, °C	24-25
	Resistance[9]	
108	Specific; internal protoplasm, ohm-cm	50
109	D.C.; fiber membrane, ohm·sq cm	10[23]
110		0.23[24]
111	Resting potential after correc. junct. pot.[25], mV	84
112	Action potential, amplitude[26], mV	151
113	Duration, msec	2.3
114	Conduction speed, m·sec^{-1}	1.7
	Electroplates[6]	
115	Temperature, °C	22-24
116	Resting potential after correc. junct. pot., mV	73.1±4.76
117	Action potential, amplitude, mV	126±15.55
118	Duration, msec	2.16±0.55
119	Conduction speed, m·sec^{-1}	1.05(0.71-1.59)
	Spinal nerves	
120	Temperature, °C	24
121	Conduction speed, m·sec^{-1}	13-17
	Lateral nerves	
122	Temperature, °C	24
123	Conduction speed, m·sec^{-1}	25
	Spinal cord	
124	Temperature, °C	24
125	Conduction speed, m·sec^{-1}	44-50
	Chick Embryo	
	Auricle	
126	Resting potential after correc. junct. pot., mV	29.2±1.3(10-41)
127	Action potential, amplitude, mV	39.2±2.0(11-81)
	Ventricle	
128	Resting potential after correc. junct. pot., mV	39.3±0.7(10-70)
129	Action potential, amplitude, mV	53.5±1.4(13-100)
	Toad (Bufo bufo)	
	Tactile fibers	
130	Fiber diameter$_f$, μ	8-15
131	Temperature, °C	22-26
132	Conduction speed, m·sec^{-1}	20-35
	Pressure fibers	
133	Fiber diameter$_f$, μ	4-5
134	Temperature, °C	22-26
135	Conduction speed, m·sec^{-1}	5-8
	Nociceptive nerve, large	
136	Fiber diameter$_f$, μ	6-9
137	Temperature, °C	22-26
138	Conduction speed, m·sec^{-1}	10-15
	Nociceptive nerve, small	
139	Fiber diameter$_f$, μ	3-5
140	Temperature, °C	22-26
141	Conduction speed, m·sec^{-1}	3-9
	Unmyelinated nerves	
142	Fiber diameter, μ	<2
143	Temperature, °C	22-26
144	Conduction speed, m·sec^{-1}	1.0-0.1
	Frog	
	Motor fibers, isolated[27]	
145	Resting potential after correc. junct. pot., mV	71
	Ventral root fibers, small diameter[28]	
146	Conduction speed, m·sec^{-1}	2-8
	Ventral root fibers, large diameter[29]	
147	Conduction speed, m·sec^{-1}	8-40
	Sciatic nerve (stripped of epineurium)	
148	Space constant, mm	2.8
	Sartorius muscle[3]	
149	Resting potential after correc. junct. pot., mV	72(max 90)
	Iliofibularis muscle[4]	
150	Resting potential after correc. junct. pot., mV	90
151	Action potential, amplitude, mV	120
	Ventricle[5]	
152	Resting potential after correc. junct. pot., mV	64.34±12
153	Action potential, amplitude, mV	84.44±10.9
	Ventricle[6]	
154	Resting potential after correc. junct. pot., mV	64.5±2.7(27-112)
155	Action potential, amplitude, mV	72.2±2.9(10-132)

	Tissues and Property	Values
	Frog, bull (Rana catesbeiana)	
	Sciatic nerve	
156	Conduction speed, m·sec^{-1}	32-46
	Frog (Rana pipiens)	
	Myelinated fiber[2]; sciatic nerve[2]	
157	Fiber diameter[28], μ	7-22
158	Resting potential, observed, mV	60-80
159	Action potential, amplitude, mV	100-130
160	Conduction speed, m·sec^{-1}	14-43
	Sartorius muscle[2, 3]	
161	Temperature, °C	20-22
162	Resting potential, observed, mV	78.4±5.3
163	After correction for junction potential, mV	97.6±5.7
	End-plate[30], sartorius muscle[2]	
164	Temperature, °C	22-23
165	Resting potential after correc. junct. pot.[31], mV	94.6±0.8
166	Action potential, amplitude[31], mV	120.9±1.5
167	Maximum rate of rise[31], V·sec^{-1}	670±22
	End-plate[30], sartorius muscle[2]	
168	Temperature, °C	22-23
169	Resting potential after correc. junct. pot.[32], mV	94.9±0.9
170	Action potential, amplitude[32], mV	117.4±1.4
171	Maximum rate of rise[32], V·sec^{-1}	750±31
	End-plate[33], sartorius muscle[2]	
172	Temperature, °C	
173	Resting potential after correc. junct. pot.[33], mV	92.8±0.5
174	Action potential, amplitude[33], mV	130.8±0.5
175	Maximum rate of rise[33], V·sec^{-1}	650±25
	Ventricle[2]	
176	Temperature, °C	12-16
177	Resting potential after correc. junct. pot., mV	62(50-90)
178	Action potential, amplitude, mV	80.8(65-115)
179	Duration[34], msec	(400-1000)
	Ventricle[2]	
180	Temperature, °C	19
181	Resting potential after correc. junct. pot., mV	64.5±17.5
182	Action potential, amplitude, mV	77.2±2.3
183	Duration, msec	8-257[35]
184	Maximum rate of rise, V·sec^{-1}	10
185	Maximum rate of fall[34], V·sec^{-1}	0.8
	Ventricle[2]	
186	Temperature, °C	22-29
187	Resting potential after correc. junct. pot., mV	54±8(40-80)
188	Action potential, amplitude, mV	74.9±9(50-110)
189	Duration[34], msec	420-1000
	Frog (Rana temporaria)	
	Sartorius muscle[2]	
190	Fiber diameter, μ	80
191	Temperature, °C	18
192	Resting potential, observed, mV	88
193	After correction for junct. potential, mV	88
194	Action potential, amplitude, mV	119
195	Duration, msec	1.5[4], 4[36]
196	Maximum rate of rise, V·sec^{-1}	470
197	Maximum rate of fall, V·sec^{-1}	86
	Sartorius muscle[37, 2]	
198	Fiber diameter[38]	137
199	Temperature, °C	19-20
200	Space constant[39], mm	2.4(2.2-2.6)
	Resistance[19]	
201	Specific; internal protoplasm, ohm-cm	250[40]
202	D.C.; fiber membrane, ohm·sq cm	4100
203	Membrane capacity[39], μF·cm^{-2}	8
204	Resting potential after correc. junt.pot., mV	88±0.6
205	Action potential, amplitude, mV	123±1
206	Conduction speed, m·sec^{-1}	1.4
	Sartorius muscle[2]	
207	Fiber diameter[38], μ	137
208	Temperature, °C	19-20
209	Space constant[41], mm	2.4; 2.15
	Resistance[41]	
210	Specific; internal protoplasm, ohm-cm	250[40]
211	D.C.; fiber membrane, ohm·sq cm	3300; 4100
212	Membrane capacity[41], μF·cm^{-2}	6.5
	Sartorius muscle[2]	
213	Resting potential after correc. junct. pot., mV	88.1-0.6
	Sartorius muscle[2]	
214	Fiber diameter[38], μ	129
215	Temperature, °C	20
216	Space constant[17], mm	1.6

/2/ Solution in internal electrode used to depolarize: 3M KCl. /3/ Solution in internal electrode used to depolarize: isotonic KCl. /4/ Spike. /9/ Determined by direct current pulses and internal electrodes. /17/ Determined by square wave pulses and internal electrodes. /20/ Locust. /21/ Cockroach. /22/ Ant.-post. direction, or non-nervous to nervous face. /23/ Nervous face. /24/ Non-nervous face. /25/ Across each face of electroplate. /26/ Electrode penetrating nervous face. /27/ Potentiometric method. /28/ Innervate slow muscle fiber system. /29/ Innervate twitch muscle fiber system. /30/ Max. rate of rise of end-plate potential, 220 V·sec^{-1}. /31/ End-plate center. /32/ 35μ from end-plate center. /33/ Distant from end-plate. /34/ Depends on cycle length. /35/ Temp. range, 30-0.2°C. /36/ Calculated on basis of conduction speed in m·sec^{-1} being twice fiber diameter in micra. /37/ End-plate response during normal impulse transmission reaches 40 mV in first 0.5 sec. /38/ Calculated from fiber diameter = $\sqrt{(4\pi r R_i / r_i)}$, /39/ Determined by square wave pulses and longitudinal electrodes. /40/ Assumed. /41/ Determined by end-plate potential and internal electrodes.

	Tissue and Property	Value
	Frog (Rana temporaria) (concluded)	
	Sartorius muscle	
217	Resistance[17] D.C.; fiber membrane, ohm·sq cm	2064
218	Membrane capacity[17], μF·cm^{-2}	10.6
	End-plate, sartorius muscle[2]	
219	Temperature, °C	20
220	Resting potential after correc. junct. pot., mV	90(75-107)
	Bundles, adductor magnus	
221	Fiber diameter, μ	75(30-130)
222	Temperature, °C	22.5
223	Space constant[14], mm Resistance[14]	0.65(0.47-1.15)
224	Specific, internal protoplasm, ohm·cm	176(131-280)
225	D.C., fiber membrane, ohm·sq cm	1500(650-4500)
226	Membrane capacity[14], μF·cm^{-2}	6(4.5-10)
	Extensor muscle, dig. IV	
227	Fiber diameter, μ	43
228	Temperature, °C	22.5
229	Space constant[14], mm Resistance[14]	1.1(0.75-1.53)
230	Specific, internal protoplasm, ohm·cm	255(206-355)
231	D.C., fiber membrane, ohm·sq cm	4300(1500-9500)
232	Membrane capacity[14], μF·cm^{-2}	4.4(2.9-5.9)
	Cells, spinal ganglion	
233	Fiber diameter, μ	80-90
234	Resting potential, observed, mV	50-90
235	Action potential, amplitude, mV	50-90
	Frog (Rana temporaria) and Cat (Felis catus)	
236	Myelinated root fibers[4] Resting potential, observed, mV	85-95
	Cat (Felis catus)	
	Motor neurones, spinal cord[2]	
237	Fiber diameter, μ	100
238	Temperature, °C	37
239	Resting potential after correc. junct. pot., mV	70
240	Action potential, amplitude, mV	(90-100)
241	Duration, msec	(300-500)
242	Maximum rate of rise, V·sec^{-1}	(200-250)
	Auricle[2]	
243	Fiber diameter, μ	30
244	Temperature, °C	36-38
245	Resting potential after correc. junct. pot., mV	60.4±4.68 (36-91)
246	Action potential, amplitude, mV	65.2±7.67
247	Maximum rate of rise, V·sec^{-1}	10
248	Maximum rate of fall[34], V·sec^{-1}	0.8-2
249		
	Cat	
	Sartorius muscle[2], vastus m.[2]	
250	Fiber diameter, μ	20
251	Resting potential after correc. junct. pot., mV	79.5±5.7
252	Action potential, amplitude, mV	116
253	Duration, msec	1.42
254	Maximum rate of rise, V·sec^{-1}	730
255	Maximum rate of fall, V·sec^{-1}	160
	Guinea Pig	
	Sartorius muscle[2]; pectoralis major[2]; biceps m.[2]	
256	Fiber diameter, μ	20
257	Resting potential after correc. junct. pot., mV	84.5±5.7
258	Action potential, amplitude, mV	121
259	Duration, msec	1.42, 1-636
260	Maximum rate of rise, V·sec^{-1}	730
261	Maximum rate of fall, V·sec^{-1}	160
	Taenia coli[2]; longitudinal smooth muscle[2]	
262	Fiber diameter, μ	<10
263	Resting potential after correc. junct. pot.[43], mV	60±9.18
	Rabbit	
	Smooth muscle, sphincter pupillae[2]	
264	Fiber diameter, μ	<10
265	Temperature, °C	35
266	Resting potential after correc. junct. pot.[44], mV	60
	Mouse, white	
	Anterior tibialis muscle[2]	
267	Temperature, °C	24-30
268	Resting potential after correc. junct. pot., mV	99.8±6.5

	Tissue and Property	Value
	Dog (Canis familiaris)	
269	Purkinje fibers, ventricle[2] Fiber diameter, μ	30
270	Temperature, °C	37-38
271	Resting potential after correc. junct. pot., mV	90±6
272	Action potential, amplitude, mV	121
273	Duration[45], msec	240-400
274	Maximum rate of rise, V·sec^{-1}	500-1000
275	Conduction speed, m·sec^{-1}	2±0.5
	Purkinje fibers, ventricle[2]	
276	Temperature, °C	38-40
277	Resting potential after correc. junct. pot., mV	89±3.2
278	Action potential, amplitude, mV	121±4
279	Duration[44], msec	500
280	Conduction speed, m·sec^{-1}	2.5
	Ventricle[2]	
281	Resting potential after correc. junct. pot., mV	90
282	Action potential, amplitude, mV	120-130
	Ventricle[2]	
283	Resting potential after correc. junct. pot., mV	80.7±7(65-95)
284	Action potential, amplitude, mV	100±8(80-120)
	Auricle[4]	
285	Resting potential after correc. junct. pot., mV	85±9
286	Action potential, amplitude, mV	100±1
	Auricle[2]	
287	Temperature, °C	37-38
288	Resting potential after correc. junct. pot., mV	85
289	Action potential, amplitude, mV	105
290	Duration[45], msec	150-250
291	Conduction speed, m·sec^{-1}	1
	Papillary muscle[4]	
292	Temperature, °C	37-38
293	Resting potential after correc. junct. pot., mV	85
294	Action potential, amplitude, mV	105
295	Duration[45], msec	150-250
296	Conduction speed, m·sec^{-1}	1
	Calf and Sheep	
	Purkinje fibers, ventricle[2]	
297	Temperature, °C Resistance[17]	38
298	Specific, internal protoplasm, ohm·cm	154
299	D.C.; fiber membrane, ohm·sq cm	1220
300	Membrane capacity[17], μF·cm^{-2}	11.3
301	Resting potential after correc. junct. pot., mV	94
302	Action potential, amplitude, mV	129
	Goat (Capra hircus)	
	Purkinje fibers, ventricle	
303	Fiber diameter[46], μ	75
304	Temperature, °C	37
305	Space constant, mm Resistance[17]	1.9
306	Specific, internal protoplasm, ohm·cm	105
307	D.C.; fiber membrane, ohm·sq cm	1940(760-3380)
308	Membrane capacity[17], μF·cm^{-2}	12.4
309	Conduction speed, m·sec^{-1}	2.2±0.5
	Purkinje fibers, ventricle[2]	
310	Fiber diameter, μ	40-100
311	Temperature, °C	37
312	Resting potential after correc. junct. pot., mV	94±8
313	Action potential, amplitude, mV	135
	Man (Homo sapiens)	
314	Ulnar nerve (most rapidly conducting fibers to muscles of hypothenar eminence) Conduction speed, m·sec^{-1}	57[47]
	Mammalia	
	Myelinated nerve fibers	
315	Fiber diameter, μ	1-20
316	Conduction speed, m·sec^{-1}	5-120
	Myelinated nerve fibers (preganglionic, autonomic)	
317	Fiber diameter, μ	<3
318	Conduction speed, m·sec^{-1}	3-15
	Unmyelinated nerve fibers (somatic, autonomic)	
319	Conduction speed, m·sec^{-1}	0.6-2

/17/ Solution in internal electrode used to depolarize: 3M KCl. /14/ Determined by direct current pulses and longitudinal electrodes. /17/ Determined by square wave pulses and internal electrodes. /34/ Depends on cycle length. /36/ Calculated on basis of conduction speed in m·sec^{-1} being twice fiber diameter in micrs. /38/ Calculated from fiber diameter = $\sqrt{(4r \times R_i/\pi)}$. /42/ With negative after potential of 1-6 msec; value of negative after-potential varies from 5-28 mV. /43/ At in situ length; membrane potential varies inversely with length. /44/ No spontaneous movements; cf FN 43. /45/ At heart rates of 130-150 beats per min. /46/ May vary 1.8 times over same fiber. /47/ Varies with age.

When a muscle is stimulated, after a brief latent period, the contractile substance shortens against a force P with a velocity v. When shortening is prevented, it exerts a maximum force P_o; when shortening is unrestrained, no force is exerted and it shortens at a maximum velocity v_o. P_o is often expressed as the force per unit area of muscle cross section (P_o/S) and v_o in muscle lengths per sec. Experimentally it is found in all muscles studied that P and v can be related by an equation of the form $(P + a)(v + b) = b(P_o + a)$, where "b" is a constant and has the dimensions of velocity, and "a" the shortening heat constant with the dimensions of force (cf Part II, Item 15). a/P_o is approximately 1/4 and largely independent of temperature. The contractile material of muscle is in series with an elastic component which must be stretched before external tension is manifest. This takes time and, in a single muscle twitch, relaxation usually sets in before P_o can be reached. The ratio of the peak twitch tension to P_o is called the twitch/tetanus ratio, and the time after the stimulus at which the peak tension is reached is known as the contraction time. The velocity of the action potential provides an index to the way in which the process of contraction spreads from the site to the inactive parts of the muscle. Resting muscle gives out a small amount of heat as a result of its metabolism. During activity the rate of heat production is much greater. The initial heat has two components: maintenance or activation heat produced when the contractile machinery is activated; and shortening heat, produced in addition in proportion to the shortening of the muscle. For a long time after activity the rate of heat production is slightly greater than the resting rate. The total amount of heat is the recovery heat.

Part I: MECHANICAL CHARACTERISTICS

	Species	Muscle	Temp °C	Latency msec l^1	Latency msec l^2	P_o/S kg/sq cm	a/P_o	Ratio: Twitch / Tetanus	Contract. Time msec	Velocity: Action Potential cm/sec	Velocity: Max. of shorten. lengths/sec[3]
1	Man	Flexors of elbow	37			2.4	0.36		70-80	400	6
2	Cat	Soleus	34-37		10			0.3	100		
3		Gastrocnemius	34-37		6.5			0.3	40		
4		Internal rectus	34-37					0.09	7.5-10		
5		Nictitating membrane			144[4]				800-1900	50-80	
6	Rabbit	Glycerol extracted fiber[5]	20			1-4	0.1				0.2
7	Rat	Diaphragm	37	1.0	1.5	1.6	0.25	0.14	16	500	11
8	Fowl	Gastrocnemius	36					0.13	50		
9	Tortoise	Retractor penis[6]	0		70	2.5	0.28		4000		0.1
10	Frog	Sartorius	20-22	1.5	2.9	2.1	0.18	0.22	25	160	10
11		Sartorius	0	7.1	15	1.7	0.25	0.72	400	55	2
12		Semimembranosus, single fibers	18-26			3.3			70		9.2
13		Semimembranosus, single fibers	0			2.8	0.16		400		3.0
14	Toad	Sartorius and semimembranosus	0	9.5	20	1.2	0.3		800	80	0.8
15	Dogfish and ray	Coracohyoid, coracomandibula	0			0.6	0.35		200	65	2.0
16	Snail	Pharyngeal retractor	15			5	0.28		300		0.15
17	Mytilus	Anterior byssal retractor	14		50	3.5	0.16	0.13		17.6	0.06
18		Pedal retractor	14		20	2.5	0.1	0.33			0.06
19	Sea anemone	Wall muscle			10,000	40			40,000		

/1/ From stimulus to beginning of early tension relaxation. /2/ From stimulus to beginning of development of positive tension or shortening. /3/ Maximum velocity of shortening. Muscle lengths/sec. /4/ Includes conduction time and neuromuscular delay. /5/ Activated by ATP. /6/ Anileofibularis.

Part II: MISCELLANEOUS PROPERTIES OF FROG MUSCLE

	Property	Value		Property	Value
1	Density, g/cu cm	1.062	9	Active state, time to fall to 50%, 0°C, (Q_{10} <= 2), msec	250
2	Diffusion constant of oxygen, at 20°C, ml/min for 1 sq cm area, 1 μ thickness; 760 mm/Hg pressure difference	0.14	10	Series elastic component, stretch produced by maximum tetanic tension, % of muscle length	4
3	Thermal conductivity, cal/min for 1 sq cm area, 1 cm thickness; 19C temperature difference	1.18×10^{-3}	11	Membrane potential, 17.4°C, mV	90
4	Volume coefficient of thermal expansion, (unloaded, resting), ml/ml x °C	0.16×10^{-3}	12	Action potential, 17.4°C, mV	124
5	Linear coefficient of thermal expansion, (unloaded, resting), cm/cm x °C	(~0.1 to 0.6) x 10^{-3}	13	Resting heat[7], cal/g x minutes	3.75×10^{-3}
6	Temperature coefficient of resting tension, (small tensions), dyne/dyne x °C	(2.4 - 6) x 10^{-3}	14	Initial heat[7]: Maintenance, cal/g x seconds	2.3×10^{-3}
7	Latency relaxation, maximum drop in tension, % of tetanic tension	0.1	15	Initial heat[7]: Shortening, cal/cm shortening x sq cm (equals "a" of Part I, if expressed in force units)	8.2×10^{-3}
8	Active state, duration of plateau, °C, (Q_{10} = 2.20), msec	35	16	Recovery heat[7], $\frac{\text{total energy developed by contraction}}{\text{initial energy developed}}$	2
			17	Maximum efficiency[7], $\frac{\text{work done x 100}}{\text{energy consumed}}$	20

/1/ Sartorius, 0°C.

Part III: MICROSCOPIC STRUCTURE AND BIREFRINGENCE CHARACTERISTICS OF MUSCLE

	Species	Muscle	Conditions	Myofibril[1] Diameter μ	Protofibril Diameter Å	Lengths of A^2 and J^3 Bands: At Rest[4] A μ	J μ	A+J μ	(A/A+J) x 100	Contraction[5] A μ	J μ	A+J μ	(A/A+J) x 100	Birefringence: At Rest x 10^{-3}	Birefringence: Contraction[6] Decrease % of Rest
1	Dog	Sartorius	Living fibers											2.60	
2	Guinea pig	Gluteus maximus[7]	Single fiber, static			1.41	0.84	2.25	62.7	1.20	1.06	2.26	53.1	1.98	
3	Mouse	Rectus abdominis	Living, whole muscle											2.61	
4	Rabbit	Psoas		0.8-1.8	200										
5		Leg muscle		0.5-1.0	50-250										
6	Lizard	Thoracalis abdominis				1.34	0.90	2.24	59.9						
7	Toad	Leg muscle		1.0	160										
8	Frog	Semitendinosus[8]	Living fiber	0.5-1.0	50-250	1.37	0.81	2.18	62.9	1.13	1.05	2.18	51.9	2.0[9]	20-30
9		Gastrocnemius	Static		40										
10		Sartorius[10]	Whole muscle static											2.07	12-14
11	Crayfish	Leg flexor				3.5	2.8	6.3	55.5						
12	Crab	Leg flexor				3.4	2.6	6.0	56.6	3.2	2.9	6.1	52.5		

/1/ Composed of filaments denoted as protofibrila. /2/ Anisotropic. /3/ Isotropic. /4/ Equilibrium length (at which tension = 0.5% of maximum tension in isometric tetanic contraction. /5/ Isometric tetanic contraction, equilibrium length. /6/ Isometric. /7/ 37°C. /8/ 17-20°C. /9/ Corrected for deviation from circular X-section by adding 18.5%. Birefringence increases with decreasing temperature by 0.5%/°C. /10/ 0°C.

Table represents an abridged listing of muscles. In no case is a complete atlas intended.

Ant. = anterior; ext. = external; inf. = inferior; int. = internal; lat. = lateral; med. = medial; post. = posterior; trans. = transverse; vert. = vertebra(e); cart. = cartilage.

	Muscle	Origin	Insertion	Action
1	Abductor digiti quinti (hand)	Pisiform; flexor carpi ulnaris tendon.	Med. surface base proximal phalanx little finger.	Abducts little finger.
2	Abductor digiti quinti (foot)	Med. and lat. tubercles calcaneus; plantar fascia.	Lat. surface base proximal phalanx little toe.	Abducts little toe.
3	Abductor hallucis	Med. tubercle calcaneus; plantar fascia.	Med. surface base proximal phalanx great toe.	Abducts, flexes great toe.
4	Abductor pollicis brevis	Navicular; ridge greater multangular; trans. carpal ligament.	Lat. surface base proximal phalanx thumb.	Abducts thumb.
5	Abductor pollicis longus	Posterior surfaces radius and ulna.	Radial side base 1st metacarpal bone.	Abducts, extends thumb.
6	Adductor brevis	Outer surface inferior ramus of pubis.	Upper part of linea aspera of femur.	Adducts, rotates, flexes thigh.
7	Adductor hallucis	Plantar fascia; base 2nd, 3rd, 4th metatarsals.	Lat. side base proximal phalanx great toe.	Adducts great toe.
8	Adductor longus	Crest, symphysis of pubis.	Linea aspera of femur.	Adducts, rotates, flexes thigh.
9	Adductor magnus	Inf. ramus pubis; ramus ischium. Ischial tuberosity.	Linea aspera of femur. Adductor tubercle of femur.	Adducts thigh. Extends thigh.
10	Adductor minimus	Sup. portion adductor magnus.	Ischium; body, ramus of pubis.	Adducts thigh.
11	Adductor pollicis	Multangular; capitate; bases 2nd, 3rd, 4th metacarpals.	Med. aspect base proximal phalanx of thumb.	Adducts, opposes thumb.
12	Anconeus	Back lat. epicondyle of humerus.	Olecranon; dorsal surface of ulna.	Extends forearm.
13	Arrectores pilorum	Papillary skin layer.	Hair follicles.	Elevates skin hairs.
14	Articularis genu	Distal 4th anterior surface of femur.	Synovial membrane of knee joint.	Lifts capsule of knee joint.
15	Aryepiglotticus	Apex arytenoid cartilage.	Lateral margin epiglottis.	Closes larynx inlet.
16	Arytenoideus, obliquus	Base muscular process arytenoid cartilage.	Apex opposite arytenoid cartilage.	Closes larynx inlet.
17	transversus	Base muscular process arytenoid cartilage.	Continuous with thyroarytenoid, base opposite cart.	Approximates arytenoid cartilages.
18	Auricularis, anterior	Superficial temporal fascia.	Cartilage of ear.	Draws ear pinna forward.
19	posterior	Mastoid process.	Cartilage of ear.	Draws pinna backward.
20	superior	Galea aponeurotica.	Cartilage of ear.	Raises ear pinna.
21	Biceps brachii	Tip coracoid process scapula; supraglenoid tuberosity.	Radius tubercle; forearm deep fascia.	Flexes forearm, supinates hand.
22	Biceps femoris	Linea aspera of femur; ischial tuberosity.	Head fibula; lat. condyle tibia; deep fascia lat. knee.	Flexes knee joint, extends hip.
23	Brachialis	Anterior aspect humerus.	Coronoid process of ulna.	Flexes forearm.
24	Brachioradialis	External supracondyloid ridge of humerus.	Lower end of radius.	Flexes forearm.
25	Buccinator	Alveolar processes maxilla, mandible, pterygomandible raphé.	Orbicularis oris at angle of mouth.	Compresses cheek, retracts mouth.
26	Bulbocavernosus	Central point perineum; median raphé of bulb.	Fascia of penis (clitoris).	Constricts bulbus urethrae.
27	Caninus	Canine fossa of maxilla.	Orbicularis oris; skin at angle of mouth.	Raises angle of mouth.
28	Chondroglossus	Inner side, base lesser cornu of hyoid bone.	Substance of tongue.	Depresses, retracts tongue.
29	Ciliaris	Scleral spur; sphincter of ciliary body.	Ciliary processes.	Visual accommodation.
30	Coccygeus	Ischial spine; sacrospinous ligament.	Lat. border lower sacrum; upper coccyx.	Supports, raises coccyx.
31	Constrictor pharyngis, inf.	Under surfaces cricoid and thyroid cartilages.	Med. raphé posterior wall of pharynx.	Constricts pharynx.
32	medius	Cornua of hyoid; stylohyoid ligament.	Middle of posterior wall of pharynx.	Constricts pharynx.
33	superior	Med. pterygoid lamina; pterygomandibular raphé.	Posterior median raphé.	Constricts pharynx.
34	Coracobrachialis	Coracoid process of scapula.	Medial aspect shaft of humerus.	Flexes, adducts arm.
35	Corrugator cutis ani	Submucous tissue within anus.	Skin surrounding anus.	Corrugates skin around anus.
36	Corrugator supercilii	Supercilliary arch of frontal bone.	Skin of forehead.	Moves eyebrows; wrinkles forehead.
37	Cremaster	Inferior margin internal oblique muscle of abdomen.	Pubic tubercle.	Elevates testis.
38	Crico-arytenoideus, lateralis	Lateral surface cricoid cartilage.	Muscular process arytenoid cartilage.	Approximates vocal folds.
39	posterior	Back of cricoid cartilage.	Muscular process arytenoid cartilage.	Separates vocal folds.
40	Cricothyroideus	Front, side of cricoid cartilage.	Lamina of thyroid cartilage.	Tenses vocal cords.
41	Deltoideus	Clavicle, acromion, spine of scapula.	Deltoid tuberosity of humerus.	Abducts, flexes, extends arm.
42	Depressor alae nasi	Incisor fossa of maxilla.	Ala and septum of nose.	Contracts nostril; depresses ala.
43	Diaphragma	Xiphoid process; costal cartilages; lumbar vertebrae.	Central tendon.	Respiration and expulsive acts.
44	Digastricus, anterior belly	Inner surface mandible near symphysis.	Hyoid bone; Intermediate tendon.	Elevates hyoid bone, lowers jaw.
45	posterior belly	Mastoid notch.	Hyoid bone; intermediate tendon.	Elevates hyoid bone, lowers jaw.
46	Epicranius (frontalis et occipitalis)	Forehead skin, occipital bone.	Galea aponeurotica.	Raises eyebrows; draws scalp backward.
47	Extensor carpi radialis brevis	External epicondyle of humerus.	Base 3rd metacarpal bone.	Extends, abducts wrist joint.
48	longus	External supracondyloid ridge of humerus.	Base 2nd metacarpal.	Extends, abducts wrist joint.
49	Extensor carpi ulnaris	External epicondyle of humerus.	Base 5th metacarpal bone.	Extends, adducts wrist joint.
50	Extensor digiti quinti proprius	External epicondyle of humerus.	Dorsum proximal phalanx of little finger.	Extends little finger.
51	Extensor digitorum brevis	Dorsal surface of calcaneus.	Extensor tendons 1st, 2nd, 3rd, 4th toes.	Extends toes.
52	communis	Lateral epicondyle of humerus.	Common extensor tendon of each finger.	Extends wrist joint and phalanges.
53	longus	Ant. fibula; lat. condyle tibia; interosseous membrane.	Common extensor tendons 4 lateral toes.	Extends toes.
54	Extensor hallucis longus	Front of tibia; interosseous membrane.	Base of terminal phalanx of great toe.	Dorsiflexes ankle joint; extends toe.
55	Extensor indicis proprius	Dorsal surface of ulna.	Common extensor tendon of index finger.	Extends index finger.
56	Extensor pollicis brevis	Dorsal surface radius and interosseous membrane.	Dorsal surface proximal phalanx of thumb.	Extends thumb.
57	Extensor pollicis longus	Dorsal surface ulna and interosseous membrane.	Dorsal surface distal phalanx of thumb.	Extends, abducts thumb.
58	Flexor carpi radialis	Medial epicondyle of humerus.	Base 2nd metacarpal.	Flexes, abducts wrist joint.
59	Flexor carpi ulnaris	Medial epicondyle humerus; medial border ulna.	Pisiform; hamulus of hamate; proximal end 5th metacarpal.	Flexes, adducts wrist joint.

60	Flexor digiti quinti brevis (foot)	Base 5th metatarsal; plantar fascia.	Lateral aspect base proximal phalanx little toe.	Flexes little toe.
61	Flexor digiti quinti brevis (hand)	Hamulus of hamate; transverse carpal ligament.	Medial side proximal phalanx little finger.	Flexes little finger.
62	Flexor digitorum brevis	Medial tuberosity calcaneus; plantar aponeurosis.	Four tendons to middle phalanx of 4 lateral toes.	Flexes toes.
63	Flexor digitorum longus	Shaft of tibia, posterior surface.	Distal phalanges lesser toes.	Flexes toes; extends foot.
64	Flexor digitorum profundus	Shaft of ulna; coronoid process.	Distal phalanges of fingers.	Flexes distal phalanges.
65	Flexor digitorum sublimis	Med. epicondyle humerus; coronoid process ulna; ant. margin of radius.	Four tendons to base of middle phalanx of each finger.	Flexes middle phalages.
66	Flexor hallucis brevis	Under surface cuboid; 3rd cuneiform.	Base proximal phalanx of great toe.	Flexes great toe.
67	Flexor hallucis longus	Posterior aspect of fibula.	Base of distal phalanx great toe.	Flexes great toe.
68	Flexor pollicis brevis	Transverse carpal ligament; ridge great multangular.	Base proximal phalanx of thumb.	Flexes thumb.
69	Flexor pollicis longus	Volar surface radius; coronoid process of ulna.	Base distal phalanx of thumb.	Flexes thumb.
70	Frontalis	Anterior portion of Epicranius; skin of forehead.	Galea aponeurotica.	Draws scalp forward, raises eyebrows.
71	Gastrocnemius	Lateral and medial condyles of humerus.	Posterior surface of calcaneus via tendo calcaneus (tendon of Achilles).	Plantar flexes ankle joint. Flexes knee joint.
72	Gemellus inferior	Tuberosity of ischium.	Greater trochanter of femur.	Rotates thigh laterally.
73	Gemellus superior	Spine of ischium.	Greater trochanter of femur.	Rotates thigh laterally.
74	Genioglossus	Mental spine of mandible.	Hyoid bone; under surface of tongue.	Protrudes and depresses tongue.
75	Geniohyoideus	Mental spine of mandible.	Body of hyoid.	Elevates, draws hyoid forward.
76	Glossopalatinus	Under surface soft palate.	Side of tongue.	Elevates tongue; constricts fauces.
77	Gluteus maximus	Lat. surface ilium; post. surface sacrum, coccyx; sacrotuberous ligament.	Gluteal tuberosity of femur; iliotibial tract.	Extends, abducts, rotates thigh outward.
78	Gluteus medius	Lateral surface of ilium.	Greater trochanter.	Abducts femur.
79	Gluteus minimus	Lateral surface of ilium.	Greater trochanter.	Abducts, medially rotates femur.
80	Gracilis	Inferior ramus of pubis.	Medial surface of tibia.	Adducts femur; flexes knee joint.
81	Hyoglossus	Body, greater cornu of hyoid bone.	Side of tongue.	Depresses tongue.
82	Iliacus	Iliac fossa and sacrum.	Lesser trochanter.	Flexes thigh, trunk on extremity.
83	Iliocostalis cervicis	Angles 3rd, 4th, 5th, 6th ribs.	Trans. processes 4th, 5th, 6th cervical vertebrae.	Extends cervical spine.
84	Iliocostalis dorsi	Upper borders angles of six lower ribs.	Angles upper 6 ribs; trans. process 7th cervical vert.	Extends thoracic spine.
85	Iliocostalis lumborum	Along with sacrospinalis.	Angles lower 6 or 7 ribs.	Extends lumbar spine.
86	Infraspinatus	Infraspinous fossa of scapula.	Greater tubercle of humerus.	Rotates humerus laterally.
87	Intercostales, ext. (11 pairs)	Lower border of rib above.	Superior border of rib below.	Draws ribs together; respiration; expulsion.
88	Intercostales, int. (11 pairs)	Lower border costal cartilage and rib above.	Superior border costal cartilage and rib below.	Draws ribs together; respiration; expulsion.
89	Interossei dorsales (foot)	Surfaces adjacent metatarsal bones.	Extensor tendons 4 lateral toes.	Abducts, flexes toes.
90	Interossei dorsales (hand)	Two heads from adjacent sides metacarpal bones.	Extensor tendons 2nd, 3rd, 4th fingers.	Abducts, flexes proximal phalanx.
91	Interossei plantares	Medial side 3rd, 4th, 5th metatarsals.	Extensor tendons 3rd, 4th, 5th toes.	Adducts, flexes toes.
92	Interossei volares	Sides of 2nd, 4th, 5th metacarpals.	Extensor tendons 2nd, 4th, 5th fingers.	Adducts, flexes proximal phalanx.
93	Interspinales	Under surface of spinous of vertebrae near apex.	Posterior part of upper surface of spine below.	Supports supinal column.
94	Intertransversarii	Transverse process of vertebra.	Transverse process of vertebra.	Lateral flexion vertebral column.
95	Ischiocavernosus	Ramus of ischium.	Crus of penis.	Assists in erection of penis.
96	Latissimus dorsi	Spines of thoracic, lumbar vertebrae; lumbodorsal fascia; ilium crest; lower ribs; inf. angle of scapula.	Groove of intertubercular sulcus of humerus.	Adducts, extends humerus.
97	Levator ani	Pelvic surface ischial spine; int. obturator fascia.	Point of perineum; anococcygeal raphé; coccyx.	Draws anus upward, forward; supports viscera.
98	Levator palpebrae superioris	Upper border optic foramen.	Upper tarsal plate.	Raises upper lid.
99	Levator scapulae	Trans. processes 4 upper cervical vertebrae.	Medial angle of scapula.	Raises scapula.
100	Levator veli palatini	Apex petrous part temporal bone; eustachian tube.	Aponeurosis of soft palate.	Raises soft palate.
101	Levatores costarum (12 pairs)	Trans. processes 7th cervical, upper 11 thoracic vertebrae.	Medial to angle of corresponding rib below.	Aid in raising ribs in inspiration.
102	Lingualis inferior	Under surface of tongue at base.	Tip of tongue.	Shortens tongue.
103	Lingualis superior	Submucosa and septum of tongue.	Tip of tongue.	Shortens tongue; raises edges, tip.
104	Longissimus capitis	Trans. process upper thoracic, lower 4 cervical vertebrae.	Mastoid process of temporal bone.	Draws head backward; rotates head.
105	Longissimus cervicis	Trans. processes upper thoracic vertebrae.	Trans. processes 2nd to 6th cervical vertebrae.	Extends cervical vertebrae.
106	Longissimus dorsi	Trans., articular processes lumbar vertebrae; fascia.	Lower ribs; trans. processes thoracic vertebrae.	Extends thoracic vertebrae.
107	Longus capitis	Trans. processes 3rd to 6th cervical vertebrae.	Basal portion occipital bone.	Flexes head.
108	Longus colli	Bodies of 1st to 3rd thoracic vertebrae.	Trans. processes 5th to 6th cervical vertebrae.	Flexes cervical vertebrae.
109	Lumbricales (foot)	Tendons of flexor digitorum longus pedis.	Extensor tendons of 4 lateral toes.	Flexes proximal phalanges, extends distal phalanges.
110	Lumbricales (hand)	Tendons of flexor digitorum profundus.	Extensor tendon of each finger.	
111	Masseter	Arch of zygoma.	Ramus and angle of mandible.	Raises mandible, closes jaws.
112	Mentalis	Incisive fossa of mandible.	Skin of chin.	Puckers chin.
113	Multifidus	Sacrum, sacroiliac ligament; mammillary processes of lumbar vertebrae; thoracic, cervical vertebrae.	Spines of vertebrae.	Extends, rotates vertebral column.
114	Mylohyoideus	Mylohyoid line of mandible.	Hyoid.	Elevates hyoid; supports mouth floor.
115	Nasalis	Maxilla.	Skin over bridge of nose.	Muscle of facial expression.
116	Obliquus abdominis externus	Lower 8 ribs at costal cartilages.	Crest of ilium; linea alba through rectus sheath.	Flex and rotate vertebral column; compress abdominal viscera.
117	Obliquus abdominis internus	Inquinal ligament; iliac crest; lumbar aponeurosis.	Lower 3 or 4 costal cartilages; linea alba; conjoined tendon to pubis.	Flex and rotate vertebral column; compress abdominal viscera.

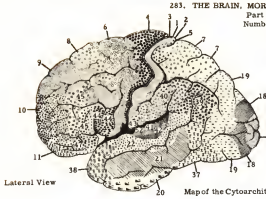
Table represents an abridged listing of muscles. In no case is a complete atlas intended.
Ant. = anterior; ext. = external; inf. = inferior; int. = internal; lat. = lateral; med. = medial; post. = posterior; trans. = transverse; vert. = vertebra(e); cart. = cartilage.

	Muscle	Origin	Insertion	Action
118	Obliquus capitis inferior	Spine of axis.	Transverse process of atlas.	Rotates atlas and head.
119	Obliquus capitis superior	Transverse process of atlas.	Occipital bone.	Extension and lateral head movements.
120	Obliquus oculi inferior	Orbital plate of maxilla.	Sclera.	Rotates eyeball upward and outward.
121	Obliquus oculi superior	Lesser wing sphenoid above optic foramen.	Sclera.	Rotates eyeball outward and downward.
122	Obturator externus	Pubis, ischium, superficial surface obturator memb.	Trochanteric fossa of femur.	Rotates thigh laterally.
123	Obturator internus	Pubis, ilium, ischium, deep surface obturator memb.	Greater trochanter of femur.	Rotates thigh laterally.
124	Occipitalis	Posterior portion of Epicranius; occipital bone.	Galea aponeurotica.	Draws scalp backward.
125	Omohyoideus	Superior border of scapula.	Lateral border of hyoid bone via central tendon.	Depresses hyoid.
126	Opponens digiti quinti	Hamulus of hamate; transverse carpal ligament.	Medial aspect of 5th metacarpal.	Rotates, adducts 5th metacarpal.
127	Opponens pollicis	Ridge greater multangular; trans. carpal ligament.	First metacarpal volar.	Opposes thumb.
128	Orbicularis oculi	Medial aspect of orbit.	Skin about eyelids.	Closes lids.
129	Palmaris brevis	Palmar aponeurosis.	Skin of medial border of hand.	Tenses palm of hand.
130	Palmaris longus	Medial epicondyle of humerus.	Transverse carpal ligament; palmar aponeurosis.	Flexes wrist joint.
131	Pectineus	Iliopectineal line; pubis.	Femur distal to lesser trochanter.	Flexes; adducts thigh.
132	Pectoralis major	Clavicle, sternum, first 6 ribs, aponeurosis of obliquus abdominis externus.	Crest of intertubercular sulcus of humerus.	Adducts, flexes, medially rotates arm; depresses shoulder.
133	Pectoralis minor	Third to 5th ribs.	Coracoid process of scapula.	Draws shoulder forward and downward.
134	Peroneus brevis	Lateral surface of fibula.	Base of 5th metatarsal.	Abducts, plantar flexes foot.
135	Peroneus longus	Lateral condyle tibia; lateral surface fibula.	First cuneiform, 1st metatarsal.	Abducts, everts, plantar flexes foot.
136	Peroneus tertius	Medial surface of fibula.	Fifth metatarsal.	Everts, dorsiflexes foot.
137	Pharyngopalatinus	Soft palate.	Aponeurosis of pharynx.	Aids swallowing.
138	Piriformis	Ilium, 2nd to 4th sacral vertebrae.	Upper border of great trochanter.	Rotates thigh outward.
139	Plantaris	Lateral condyle of femur.	Posterior part of calcaneus.	Plantar flexes foot.
140	Platysma	Fascia of cervical region.	Mandible and skin around mouth.	Wrinkles neck skin; depresses jaw.
141	Popliteus	Lateral condyle of femur.	Back of tibia.	Flexes leg; rotates leg inward.
142	Procerus	Skin over nose.	Skin of forehead.	Draws down eyebrows.
143	Pronator quadratus	Volar surface of ulna.	Volar surface of radius.	Pronates hand.
144	Pronator teres	Medial epicondyle of humerus; coronoid of ulna.	Lateral surface of radius.	Pronates hand.
145	Psoas major	Lumbar vertebrae and fascia.	Lesser trochanter of femur.	Flexes trunk; flexes, medially rotates thigh.
146	Psoas minor	Last thoracic, first lumbar vertebrae.	Iliopectineal eminence of pubis.	Flexes trunk on pelvis.
147	Pterygoideus externus	Sphenoid; lateral pterygoid plate.	Mandible neck; temporomandibular joint capsule.	Protrudes mandible; opens jaws.
148	Pterygoideus internus	Lateral pterygoid plate; maxilla tuberosity.	Medial surface of mandible angle.	Closes jaws.
149	Pyramidalis	Front of pubis; anterior pubic ligament.	Linea alba.	Tenses abdominal wall.
150	Quadratus femoris	Ischial tuberosity.	Quadrate tubercle of femur.	Adducts, laterally rotates femur.
151	Quadratus labii inferioris	Mandible.	Skin about mouth.	Depresses lower lip.
152	Quadratus labii superioris	Maxilla.	Skin about mouth.	Raises upper lip.
153	Quadratus lumborum	Iliac crest; lumbodorsal fascia; lumbar vertebrae.	Last rib.	Laterally flexes lumbar vertebrae.
154	Quadratus plantae	Calcaneus and plantar fascia.	Tendons of flexor digitorum longus.	Aids in flexion of toes.
155	Quadriceps femoris	Rectus femoris and 3 vastus muscles.		Extends leg.
156	Rectus abdominis	Pubic crest.	Xiphoid; 5th to 7th costal cartilage.	Flexes lumbar vertebrae; supports abdomen.
157	Rectus capitis anterior	Lateral portion of atlas.	Occipital bone.	Flexes, supports head.
158	Rectus capitis lateralis	Upper surface transverse process of atlas.	Jugular process occipital bone.	Flexes, supports head.
159	Rectus capitis post. major	Spine of epistropheus.	Occipital bone.	Extends head.
160	Rectus capitis post. minor	Posterior tubercle of atlas.	Occipital bone.	Extends head.
161	Rectus femoris	Ant. inf. spine of ilium; dorsum ilii.	Patella; tubercle of tibia.	Extends leg; flexes thigh.
162	Rectus oculi inferior	Circumference of optic foramen.	Under side of sclera.	Adducts, rotates eye downward and inward.
163	Rectus oculi lateralis	Margin optic foramen, sphenoidal fissure.	Outer side of sclera.	Abducts eyeball.
164	Rectus oculi medialis	Circumference of optic foramen.	Inner side of sclera.	Adducts eyeball.
165	Rectus oculi superior	Upper border optic foramen.	Upper aspect of sclera.	Adducts, rotates eye upward and inward.
166	Rhomboideus major	Spines of 2nd to 5th thoracic vertebrae.	Vertebral margin of scapula.	Retracts, elevates scapula.
167	Rhomboideus minor	Spines 7th cervical to 1st thoracic vertebrae.	Vertebral margin of scapula.	Retracts, elevates scapula.
168	Risorius	Fascia over masseter.	Skin at angle of mouth.	Draws angle of mouth laterally.
169	Rotatores spinae (11 pairs)	Transverse process of thoracic vertebrae below.	Lamina of thoracic vertebrae above.	Extend, rotate vertebral column.
170	Sartorius	Anterior superior spine of ilium.	Tibia, upper medial.	Flexes thigh and leg.
171	Scalenus anterior	Transverse processes 3rd to 6th cervical vertebrae.	Tubercle of first rib.	Raises 1st rib.
172	Scalenus medius	Transverse processes 2nd to 6th cervical vertebrae.	First rib.	Raises 1st rib.
173	Scalenus posterior	Tubercles 4th to 6th cervical vertebrae.	Second rib.	Raises 1st and 2nd ribs.
174	Semimembranosus	Ischial tuberosity.	Medial condyle of tibia.	Flexes leg; extends thigh.
175	Semispinalis capitis	Trans. processes upper 6 thoracic, lower 4 cervical vertebrae.	Occipital bone.	Extends head.

175	Semispinalis cervicis	Trans. processes upper 6 thoracic, lower 4 cervical vertebrae.	Spines 2nd to 5th cervical vertebrae.	Extends, rotates vertebral column.
176	Semispinalis dorsi	Trans. processes 6th to 10th thoracic vertebrae.	Spines last 2 cervical, first 4 thoracic vertebrae.	Extends, rotates vertebral column.
177	Semitendinosus	Ischial tuberosity.	Medial aspect proximal portion of tibia.	Flexes leg; extends thigh.
178	Serratus anterior	Upper 8 or 9 ribs.	Vertebral border of scapula.	Draws scapula forward; rotates scapula to raise shoulder in abduction of arm.
179	Serratus posterior inferior	Spines 2 lower thoracic, upper 2-3 lumbar vertebrae.	Inferior border of 4 lower ribs.	Lowers ribs in expiration.
180	Serratus posterior superior	Ligamentum nuchae; spines upper thoracic vertebrae.	Second to 5th ribs.	Raises ribs in inspiration.
181	Soleus	Fibula; popliteal fascia; tibia.	Calcaneus by tendo calcaneus (Achilles).	Planter flexes ankle joint.
182	Sphincter ani externus	Tip of coccyx; surrounding fascia.	Tendinous center of perineum.	Closes anus.
183	Sphincter pupillae	Circular fibers of iris.		Contracts pupil.
184	Sphincter urethrae membranaceae	Ramus of pubis.	Median raphé of urethra.	Compresses urethra.
185	Spinalis capitis	Spines upper thoracic, lower cervical vertebrae.	Occipital bone.	Extends head.
186	Spinalis cervicis	Spines lower cervical, upper thoracic vertebrae.	Spines 2nd to 4th cervical vertebrae.	Extends vertebral column.
187	Spinalis dorsi	Spines of lower 2 thoracic, upper 2 lumbar vertebrae.	Spines upper thoracic vertebrae.	Extends vertebral column.
188	Splenius capitis	Ligamentum nuchae; last cervical, upper thoracic vertebrae.	Occipital bone.	Extends, rotates head.
189	Splenius cervicis	Spinous processes 3rd to 6th thoracic vertebrae.	Transverse processes 2-3 upper cervical vertebrae.	Extends, rotates head and neck.
190	Stapedius	Interior of pyramid of tympanum.	Posterior surface of neck of stapes.	Retracts stapes.
191	Sternocleidomastoideus	Two heads, sternum and clavicle.	Mastoid process.	Flexes, rotates head.
192	Sternohyoideus	Manubrium of sternum.	Lower border of body of hyoid.	Depresses hyoid and larynx.
193	Sternothyroideus	Manubrium of sternum.	Thyroid cartilage.	Depresses thyroid cartilage.
194	Styloglossus	Styloid process.	Side of tongue.	Raises and retracts tongue.
195	Stylohyoideus	Styloid process.	Hyoid.	Draws hyoid and tongue upward.
196	Stylopharyngeus	Styloid process.	Lateral wall of pharynx.	Raises and dilates pharynx.
197	Subanconeus	Posterior distal surface of humerus.	Posterior aspect of elbow joint.	Pulls capsule back in elbow joint extension.
198	Subclavius	1st costal cartilage and rib.	Clavicle.	Depresses lateral end of clavicle.
199	Subcostales	Inner surface of ribs.	Inner surface 1st, 2nd, 3rd rib below.	Raises ribs in inspiration.
200	Subscapularis	Subscapular fossa of scapula.	Lesser tubercle of humerus.	Rotates humerus medially.
201	Supinator	Lat. epicondyle of humerus; ulna, elbow joint fascia.	Radius.	Supinates hand.
202	Supraspinatus	Supraspinous fossa of scapula.	Greater tubercle of humerus.	Abducts humerus.
203	Temporalis	Temporal fossa and fascia.	Coronoid process of mandible.	Closes jaws.
204	Tensor fasciae latae	Iliac crest.	Iliotibial band of fascia lata.	Flexes, abducts thigh.
205	Tensor tympani	Cartilaginous portion of auditory tube.	Manubrium of malleus.	Tenses membrana tympani.
206	Tensor veli palatini	Scaphoid fossa of sphenoid, wall of auditory tube.	Aponeurosis of soft palate.	Tenses soft palate; opens auditory tube.
207	Teres major	Axillary margin of scapula.	Crest of intertubercular sulcus of humerus.	Adducts, extends, medially rotates arm.
208	Teres minor	Axillary margin of scapula.	Greater tubercle of humerus.	Laterally rotates arm.
209	Thyro-arytenoideus	Lamina of thyroid cartilage.	Muscular process of arytenoid cartilage.	Relaxes, shortens vocal cords.
210	Thyro-epiglotticus	Lamina of thyroid cartilage.	Epiglottis	Closes inlet of larynx.
211	Thyrohyoideus	Thyroid cartilage.	Lower border greater cornu of hyoid.	Raises and changes form of larynx.
212	Tibialis anterior	Tibia and interosseous membrane.	First cuneiform and metatarsal, dorsal.	Dorsiflexes and inverts foot.
213	Tibialis posterior	Fibula; tibia; interosseous membrane.	Bases metatarsals and tarsals, except talus.	Plantar flexes and inverts foot.
214	Transversus abdominis	Costal cartilages lower 6 ribs; lumbodorsal fascia; iliac crest; inguinal ligament.	Lines alba through rectus sheath; conjoined tendon to pubis.	Compresses abdominal viscera.
215	Transversus linguae	Median raphé of tongue.	Dorsum and sides of tongue.	Alters shape of tongue.
216	Transversus perinei profundus	Inferior ramus of ischium.	Median raphé of perineum.	Draws back central point of perineum.
217	Transversus perinei superficialis	Tuberosity of ischium.	Central tendon of perineum	Tensor of central point of perineum.
218	Transversus thoracis	Mediastinal surface of xiphoid and body of sternum.	Second to 6th costal cartilage.	Narrows the chest.
219	Trapezius	Occipital bone; ligamentum nuchae; spines of 7th cervical and all thoracic vertebrae.	Clavicle; acromion; spine of scapula.	Rotates scapula to raise shoulder in abduction of arm; draws scapula backward.
220	Triangularis	Lower border of mandible.	Angle of mouth.	Pulls mouth corners downward.
221	Triceps brachii	Infraglenoid tuberosity; shaft of humerus; (three heads).	Olecranon of ulna.	Extends forearm; adducts, extends arm.
222	Uvulae	Posterior nasal spine.	Uvula.	Raises uvula.
223	Vastus intermedius	Anterior, lateral aspects of femur.	Patella; common tendon of quadriceps femoris.	Extends leg.
224	Vastus lateralis	Capsule of hip joint, lateral aspect of femur.	Patella; common tendon of quadriceps femoris.	Extends leg.
225	Vastus medialis	Medial aspect of femur.	Patella; commen tendon of quadriceps femoris.	Extends leg.
226	Verticalis linguae	Dorsal aspect of tongue.	Sides and base of tongue.	Alters shape of tongue.
227	Vocalis	Thyroid cartilage.	Vocal process of arytenoid cartilage.	Shortens vocal cords.
228	Zygomaticus	Zygomatic bone in front of temporal process.	Angle of mouth.	Draws mouth backward, upward.

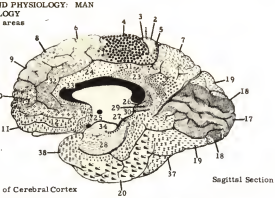
Part I: MORPHOLOGY

Numbers represent areas of Brodmann.

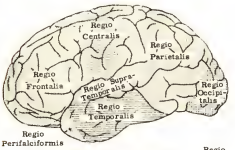


Lateral View

Map of the Cytoarchitectonic Areas of Cerebral Cortex



Sagittal Section

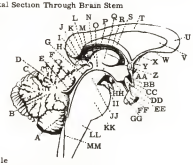


Sectoral Map of the Cerebral Cortex



Median Sagittal Section Through Brain Stem

A=Epithelial roof and choroid plexus of 4th ventricle
B=Inferior vermis of cerebellum
C=Plasma prima
D=Sup. verm. of cerebellum
E=4th ventricle
F=Anterior medullary velum
G=Cerebral aqueduct
H=Lamina quadrigemina
I =Splenium of corpus callosum
J =Pineal body
K=Posterior commissure
L=Supraneal recess
M=Habenular commissure
N=Habenula
O=Hypothalamic sulcus
P=Choroid plexus of 3rd ventricle
Q=Massa intermedia
R=Epithelial roof of 3rd ventricle
S=Body of fornix
T=Corpus callosum
U=Genu of corpus callosum
V=Septum pellucidum
W=Rost. of corr. callosum
X=Lamina rostralis
Y=Columna fornicis
Z=Interventricular foramen
AA=Anterior commissure
BB=Lamina terminalis



CC=Optic recess
DD=Optic chiasma
EE=Infundibulum
FF=Hypophysis
GG=Mammillary body
HH=Oculomotor nerve
II=Subthalamus
JJ=Tegmentum of mesencephalon
KK=Pons
LL=Medula
MM=Central canal

Part II: VARIOUS BRAIN REGIONS AND THEIR FUNCTIONS

		Region	General Functions	Sub-regions	Known Functions
				Telencephalon	
1		Cerebral cortex	Highest level of integration; symbolism, memory, forecasting.	Prefrontal, frontal, parietal, occipital, temporal.	Association: autonomic; general motor, sensory; visual; auditory.
2	PROSENCEPHALON	Rhinencephalon	Olfaction, "visceral brain," emotion.	Olfactory bulb, cortex; amygdala; hippocampus; fornix; mammillary bodies.	Association: autonomic-visceral integration; olfaction.
3		Corpus striatum	Smoothing of motor behavior; inhibition of posture, movement patterns; extrapyramidal relay. [1]	Caudate nucleus, putamen, globus pallidus.	Forebrain association centers; motor relay (globus pallidus) for putamen.
				Diencephalon	
4		Epithalamus		Habenular nucleus.	
5		Thalamus	Sensory relay to cortex; thalamocortical circuits.	Anterior, midline, medial, lateral, posterior, pulvinar, ventral.	Cortical relay nuclei: anterior, emotion(?); medial and ventral, sensory; pulvinar, gnostic and practic. Unspecific intralaminar nuclei. Basal ganglia relay ventromedian.
6		Metathalamus		Medial, lateral geniculate.	Medial: acoustic to supratemporal plane; lateral: visual to striate area.
7		Subthalamus		Subthalamic nucleus.	Hemiballismus.
8		Hypothalamus	Principal forebrain center for integration of visceral functions involving autonomic nervous system. [2]	Anterior, middle, lateral, posterior.	Generally anterior part trophotropic (parasympathetic); posterior part ergotrophic (orthosympathetic).
9		MESENCEPHALON	Postural reflexes; nuclei for cranial nerves.	Superior colliculus, inferior colliculus, substantia nigra, red nucleus, tegmentum, reticular formation (part of), basis peduncles, nucleus N III, IV, V (part of).	Relay for visual reflexes (protective), auditory reflexes, extrapyramidal junction of striatal and cortical influences, contributes to righting reflexes, tracts; facilitatory and inhibitory influences on motor performance.
				Metencephalon	
10	RHOMBENCEPHALON	Cerebellum	Maintenance of posture; equilibrium; coordination, smoothing of complex movements.	Corpus cerebelli, anterior posterior lobe, flocculonodular lobe.	"Vestibulocerebellum" (equilibration, maintenance of posture); postural reflexes, stabilizing, smoothing more complex movements initiated in cortex; facilitation of posture change.
11		Pons		Pontine nucleus, reticular formation, cerebellar peduncles, tracts, nucleus V (part of).	Relay between cerebro-cerebellar, motor inhibitory areas.
				Myelencephalon	
12		Medulla oblongata	Reflex center for cardiac vasomotor, vomiting, deglutition, respiratory, gustatory, facial reflexes.	Nucleus V (part of), IX, XI, XII, inferior olivary, tracts; reticular nuclei of medullary tegmentum.	Posture.

[1] Energy and water exchange; sexual function; sleep; vasomotor.

Part III: META- AND DORSAL THALAMUS

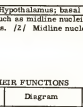
A = associational; D = diffuse associational; I = internal relay; E = external relay; U = unclassified or doubtful.

	Nucleus	Function	Afferents	Efferents
1	Medialis dorsalis	A	Principal: some from medio ventral region (hypothalamus).	Frontal granular cortex.
2	Lateralis posterior	A	Principal: parietal cortex. Diffuse: sensorimotor, limbic, auditory, visual, frontal cortices. Nuclei, Lines 5-9 (q.v.).	Parietal field.
3	Lateralis anterior	A	Principal: parietal cortex. Diffuse: sensorimotor, auditory, visual cortices. Nuclei, Lines 5-9 (q.v.).	
4	Pulvinar	A	Principal: parietal association. Diffuse: frontal, sensorimotor, limbic, auditory, visual cortices. Subcortical: ventral posterior nucleus of thalamus. Nuclei, Lines 5-9 (q.v.).	Posterior parietal and temporal cortex, superior parietal lobule, posterior Sylvian region, supramarginal gyrus, temporo-occipital region, area 18, superior colliculus and pretectum, posterior parietal, temporal and occipital (parasensory) fields.
5	Centrum medianum	D	Subcortical: reticular formation, other intralaminar[1] thalamic nuclei.	Subcortical: caudate nucleus, corpus striatum.
6	Centralis medialis	D	Reticular formation. Intralaminar thalamic nuclei.	Cortical associational areas: frontal, cinguate, orbital. Caudate nucleus.
7	Centralis lateralis			
8	Ventralis anterior			
9	Reticularis anterior	D	Reticular formation; other intralaminar thalamic nuclei.	
10	Anterodorsalis	I	Corresponding opposite nucleus.	Retrosplenial region(?).
11	Anteromedialis	I	Mammillothalamic tract; limbic cortex. Nuclei, Lines 5-9, (q.v.).	Anterior gyrus cinguli.
12	Anteroventralis	I	Subcortical: nuclei, Lines 5-9, (q.v.); mammillothalamic tract. Cortical: gyrus cinguli.	Posterior gyrus cinguli.
13	Ventral anterior	I	Principal: globus pallidus. Diffuse from orbital, parietal, frontal, sensorimotor, limbic cortices. Nuclei, Lines 5-9 (q.v.).	Globus pallidus; prefrontal cortex.
14	Ventralis lateralis	I	Principal: superior cerebellar peduncle.	Precentral motor cortex; areas 4 and 6. Brachium conjunctivum.
15	Ventral medial	I		Globus pallidus; lateral frontal cortex.
16	Medial geniculate body	E	Inferior colliculi and parabigeminal body; auditory cortex.	Auditory cortex; parvicellular and magnocellular to temporal cortex in lower wall of Sylvian fissure.
17	Lateral geniculate body	E	Ganglion cell layer of retina.	
18	Ventral posterolateral	E	Medial lemniscus; spinothalamic tracts; sensorimotor cortex.	Sensorimotor cortex.
19	Ventral posteromedial	E	Trigeminal lemniscus; trigeminal thalamic tract.	Sensorimotor cortex.
20	Reticularis lateralis (posterior)	U	Unclassified or doubtful.	Cortex.
21	Midline[2]	D/U	Spinothalamic tract; medial lemniscus.	Hypothalamus; basal ganglia; lateral thalamus nuclei.

[1] Denotes nuclei not only adjacent to internal medullary lamina of thalamus but also others (such as midline nuclei, reticularis anterior and ventralis anterior), which when stimulated can evoke cortical and intrathalamic recruiting responses. [2] Midline nuclei: rhomboideus, reuniens, paracentralis, parafascicularis, paraventricularis (anterior and posterior), parataenialis.

Part IV: VARIOUS CORTICAL CEREBRAL REGIONS AND THEIR FUNCTIONS

	Function	Gross Region	Diagram	Area[1]	Principal Connected Pathways and Areas
1	Vision	Occipital (striate cortex)		17(OC)	Optic radiation; lateral geniculate body of the thalamus; optic tract; chiasm; optic nerve; retina.
2	Visual elaboration	Occipital (parastriate) and Parietal (preoccipital)		18(OB) 19(OA)	Reticular formation of brain stem; areas PH, FC, LC_2 and TE of Economo; areas 37, 8, 23, 21 of Brodman.
3	Hearing (auditosensory)	Temporal (Heschl's gyrus)		41(TC)	Auditory radiation; medial geniculate body inferior colliculus; nucleus of lateral lemniscus; superior olive: dorsal and ventral cochlear nucleus in brain stem; cochlear nerve; spiral ganglion; hair cells in Organ of Corti.
4	Hearing (auditopsychic)	Temporal		42(TB) 22(TA)	

	Function	Gross Region	Diagram	Area[1]	Principal Connected Pathways and Areas
5	Equilibration	Temporal (first convolution)		22(TA) (?)	Probably similar to auditory mechanism.
6	Olfaction	Temporal (Piriform area)		28(HB) 34(HA)	Lateral root; olfactory tract; olfactory bulb; fila olfactoria.
7	Somatic sensation	Parietal (post central convolution)		3(PA) 1(PB) 2(PC)	Connected through posteroventral nuclei with medial and trigeminal fillets and spinothalamic tract; dorsal root; sensory root ganglion; peripheral sensory nerves.
8	Sensory elaboration (leg skills)	Parietal (superior parietal lobule)		5(PE_m) 7$_A$(PE_p)	Association fibers with areas FC, FD_p, FEB_m, OA, FC, FD_Δ of Economo; areas 4, 44, 19, 8, 46 of Brodmann.

[1] Areas of Brodmann are given numerically, followed in parentheses by associated areas of Economo. The latter have literal designations.

Part IV: VARIOUS CORTICAL CEREBRAL REGIONS AND THEIR FUNCTIONS (Concluded)

	Function	Gross Region	Diagram	Area[1]	Principal Connected Pathways and Areas
9	Sensory elaboration (arm skills)	Parietal (inferior parietal lobule)		40(PF) 39(PG)	Association fibers with areas PC, TB and OA of Economo; areas 1, 42, 19 of Brodmann.
10	Speech (motor)	Frontal (3rd convolution, dominant hemisphere) Broca's area		44(FCB_m)	Receives afferents from PB of Economo, area 3 of Brodmann, sends impulses to areas FA and FE of Economo, areas 4 and 5 of Brodmann.
11	Speech (sensory) (Gnosis)	Parietal (lower parietal lobule, dominant hemisphere)		40(PF) 39(PG)	Association fibers with areas PC, TB, OA of Economo; areas 1, 42, 19 of Brodmann.
12	Memory	Temporal		Areas not definite	
13	Elaboration of conclous thought	Frontal		9, 10, 11, 12, 13, 14(FD and variants) 24(LA)	Orbitofrontal cortex (areas 9, 10, 11, 12 of Brodmann) and posterior and medial orbital gyri (areas 13 and 14 of Walker) are connected to dorsomedial nuclei of thalamus which has hypothalamic connections. The anterior cingulate gyrus (area 24) is projection area of anterior nuclei of thalamus.
14	Motion	Frontal (precentral area, motor and premotor)		4(FA) 6(FB)	Internal capsule, pyramidal decussation, corticospinal tracts, anterior horn cells, motor roots. Connected by way of latero-ventral nucleus and the superior cerebellar peduncle with the spinocerebellar afferents.

/1/ Areas of Brodmann are given numerically, followed in parentheses by associated areas of Economo. The latter have literal designations.

Part V: BRAIN TRACTS

C = cervical, S = sacral, T = thoracic.

	Tract	Origin	Termination	Pathway	Function
1	Acoustico-optic	Inferior colliculus.	Homolateral superior colliculus.	Diffuse.	Unknown.
2	Allen's fasciculus[1]	Solitary nucleus.	Ventral column: C3-T6.	Lateral funiculus along dorso-lateral edge of ventral column.	Associated with respiratory control.
3	Part of central tegmental fasciculus	Central gray of cerebral aqueduct,	About sac of inferior olive.	Flattened bundle running through tegmentum, oblique to horizontal plane, lateral to medial longitudinal fasciculus	
4	Arcuate fasciculus	Cerebral cortex of basal frontal lobes.	Cortex of temporal, lower parietal and occipital regions	Through base of angular gyrus into interior and middle frontal gyrus; in parietal and frontal opercula over upper border of insula.	Association bundle.
5	Bigeminopontine	Nucleus of perabigeminal body.	Pontine nuclei (lateral cells).	Lateral to medial lemniscus to middle strata of pons.	
6	Central acoustic	Contralateral and homolateral cochlear nucleus and olivary complex; nuclei of central acoustic tract.	Medial geniculate body.	With lateral lemniscus to ventro-lateral surface of inferior colliculus; runs in brachium of inferior colliculus.	Auditory.
7	Cortico-habenular fibers	Hippocampus (and cingulate gyrus).	Medial habenular nucleus.	Via fornix and medullary stria of diencephalon.	
8	Corticospinal, lateral	Cerebral cortex.	Contralateral ventral column.	Internal capsule; cerebral peduncle; decussation of pyramids, lateral corticospinal tract.	Motor.
9	Corticospinal, ventral	Cerebral cortex.	Ipsilateral ventral column.	Internal capsule; peduncle, ventral corticospinal tract about anterior median fissure of cord.	Motor.
10	Cortico-tegmental fasciculus	Anterior central gyrus.	Diffuse tegmental nucleus.	Intermingled with corticospinal fibers, mostly in lateral 2/5 of cerebral peduncle.	
11	Cuneste fasciculus	Dorsal root ganglia C 1-T6.	Cuneate nucleus.	Lateral portion of dorsal funiculus above T6.	Proprioception. Discriminative touch (upper extremities).
12	Dorsolateral fasciculus (Lissauer)	Dorsal root ganglia.	Substantia gelatinosa (Rolando), and nucleus proprius within 2-4 segments.	Dorsolateral to substantia gelatinosa of dorsal horn of gray matter.	Pain, temperature and light touch.
13	Fastigiobulber fasciculus	Fastigial nuclei.	Tegmental motor nuclei	Mingled with uncinate fasciculus of Russel in juxtarestiform body.	Cerebellar inhibitory path from anterior lobe to inhibitory region of bulbar reticular substance.
14	Fastigiospinal fasciculus	Fastigial nuclei.	Upper cervical segments of cord.	By way of spinal root of vestibular nerve.	Vestibular reflex connections to cervicel musculature.
15	Fastigiovestibular fasciculus	Fastigial nucleus.	Contralateral superior, lateral, medial and spinal vestibular nuclei.	Through brachium conjunctivum in front of dentate nucleus, forming three limbs to distribute to vestibular nuclei.	
16	Frontal fasciculus, superior (Burdach's)	Basal frontal regions of cortex.	Temporal, lower parietal and occipital cortex.	Dorsal to insula.	Association fibers.
17	Frontopontine fasciculus	Posterior portions of superior and middle frontal gyri bordering on precentral gyrus.	Pontine nuclei.	Extreme medial and lateral portions of cerebral peduncle.	Cortical relay fibers to middle lobe of cerebellum.
18	Fasciculus gracilis (Goll)	Dorsal root ganglia T6-S5.	Nucleus gracilis.	Medial portion of dorsal funiculus.	Proprioception. Discriminative touch (lower extremities).
19	Habenulo-peduncular fasciculus[2]	Habenular nuclei.	Interpeduncular nucleus.	Runs ventrolaterally; arches beneath centrum medianum through medial border of red nucleus and down along midventral line.	

/1/ Solitario spinal. /2/ Retroflex bundle of Meynert.

	Tract	Origin	Termination	Pathway	Function
20	Habenulo-tegmental	Habenular nuclei.	Dorsal tegmental nucleus.		
21	Descending hypothalamic[3]	Dorsomedial nuclei, posterior and lateral hypothalamic areas and periformical areas.	Autonomic cells in medulla oblongata and intermediolateral cell column of cord.	Decends between mammillary body and red nucleus to ipsilateral reticular formation; dorsal to substantia nigra, then to region of vestibular fiber complex.	
22	Interfascicular fasciculus (Schultze)	Descending fibers of posterior funiculus.	Nucleus proprius of gray matter.	Between and mingled with fasciculus gracilis and cuneatus.	Reflex collaterals.
23	Interstitiospinal (of Cajal)	Mesencephalon, region of posterior commisaure.	Intermediolateral cell column of cord (C8-T1).	Descends along ventromedian sulcus of cervical cord.	
24	Laterocerebellar	Lateral nucleus of medulla.	Cerebellum.	Runs with external arcuate fibers.	
25	Longitudinal fasciculus, dorsal (Schutz)	Hypothalamus and dorsal tegmental nucleus.	Somato-motor and autonomic motor nuclei of brain stem.	Continued into ventral fasciculus proprius of cord.	
26	Longitudinal fasciculus, inferior	Occipital cortex.	Temporal cortex.		Association fibers.
27	Longitudinal fasciculus, medial	Mesencephalon, at level of posterior commisaural nuclei.	Through medulla, continued in cord as sulcomarginal fasiculus of Marie.	Bilateral, about midventral line between central gray matter and tectospinal fasiculus (in medulla).	Contains vestibular reflex fibers, fibers from reticular nuclei, abducens nucleus.
28	Mammillary fasciculus	Medial mammillary nuclei.	Anterior thalamic nuclei and tegmentum.	Runs dorsally from mammillary bodies, then bifurcates; one limb continues dorsally, the other caudally.	
29	Mammillotegmental fasciculus	Medial and lateral mammillary nuclei.	Tegmentum.	Initially a component of the principal mammillary fasciculus which it leaves to run caudally.	
30	Mammillothalamic fasciculus (Vicq d'Azyr)	Medial and lateral mammillary nuclei.	Anterior nuclear mass of thalamus.	Dorsorostrally through medial thalamic wall.	
31	Olfactohabenular	Basal olfactory region, olfactory striatum, and medial part of amygdaloid complex.	Lateral habenular nucleus.	Lateral portion of medullary stria of diencephalon.	
32	Olfactopeduncular	Region about olfactory tubercle and putamen.	Region of substantia nigra.	Caudally beneath pallidum; ventral to internal capsule; medial border of peduncle.	
33	Olfactory	Olfactory bulb.	In three stria; medial, intermediate, and lateral olfactory stria.	Lies between gyrus rectus and medial orbital gyrus, covering olfactory sulcus.	Olfaction.
34	Olivo-cochlear bundle	Nuclei of olivary complex.	Organ of Corti.	Via auditory nerve.	Inhibition of neural response from Organ of Corti.
35	Olivospinal (Helweg)	Inferior olive.	Spinal gray, ventral column.	At junction of lateral and ventral funiculi.	
36	Optic	Ganglion cells of retina.	Lateral geniculate and/or superior colliculus.	Tract encircles thalamus ventrally	Vision.
37	Perpendicular fasciculus	Inferior parietal lobule.	Fusiform gyrus.	Obliquely dorsomedially and ventrolaterally.	Association.
38	Probst's	Sensory cells associated with nucleus V in area of cerebral aqueduct or lateral reticular nucleus of the mesencephalon.	Intercalated nucleus and dorsal vagal nucleus.	Ventrolateral to solitary fasciculus and dorsomedial to the nucleus of the spinal tract of V.	Appears to link various parts of the trigeminal system; relates masticatory movements with salivation.
39	Reticulospinal fasciculus, lateral, direct	Reticular substance.	Gray matter of cord.	Lies in region of overlap of lateral corticospinal and rubrospinal tracts.	Extrapyramidal aspects of motor function.
40	Reticulospinal fasciculus, ventral, crossed	Reticular substance.	Gray matter of cord.	Ventrolateral to ventral corticospinal fibers.	Inhibitory pyramidal motor function.
41	Rubrospinal	Red nucleus.	Gray matter of cord.	Ventromedial to, and overlapping, lateral corticospinal tract.	Extrapyramidal function in man obscure.
42	Septomarginal fasciculus	Collaterals of dorsal funiculus fibers (fasciculus cuneatus).	Gray matter of cord.	Along posterior median sulcus in middle of posterior funiculus.	Proprioceptive reflex connections.
43	Solitary fasciculus	Fibers from cranial nerves VII, IX, and X.	Solitary nucleus.	Dorsomedial to spinal root of V; extends from level of medullary stria to caudal end of medulla.	Visceral afferent; oral end concerned with taste.
44	Spinal of trigeminal nerve	Cells of origin in semilunar ganglion.	Nucleus of spinal trigeminal tract.	Medial to restiform body; in position of Lissauer's zone and gelatinous substance of spinal cord.	Pain and temperature from face region.
45	Spinocerebellar fasciculus, ventral	Border cells about medial border of centralateral ventral column and cells about dorsal nucleus of Clark.	Vermis of anterior lobe of cerebellum.	On periphery of cord ventral to dorsal spinocerebellar, and lateral to lateral spinothalamic tract.	Exteroceptive.
46	Spinocerebellar fasciculus,dorsal (Flechsig)	Dorsal horn and dorsal nucleus of Clark.	Cortex of anterior cerebellar lobe, uvula and pyramis of vermis.	On periphery of lateral funiculus of cord.	Proprioceptive and exteroceptive.
47	Spinoölivary (Helweg)	Dorsal horn of spinal cord.	Inferior olive.	Ventral and superficial part of lateral funiculus between lateral and ventral spinothalamic tracts.	

[3] Not yet demonstrated anatomically.

283. THE BRAIN, MORPHOLOGY AND PHSIOLOGY: MAN (Concluded)

Part V: BRAIN TRACTS (Concluded)

C = cervical; S = sacral, T = thoracic.

	Tract	Origin	Termination	Pathway	Function
48	Spinothalamic, lateral	Dorsal horn of gray matter. Proper nucleus of contralateral dorsal horn.	Tectum of midbrain. Posterolateral ventral nucleus of thalamus.	Ventral and superficial part of lateral funiculus. Lateral funiculus just medial to ventral spinocerebellar tract.	Pain and temperature from limbs and trunk.
49	Spinothalamic, ventral	Proper nucleus of contralateral dorsal horn.	Posterolateral ventral nucleus of thalamus.	Lateral portion of ventral funiculus.	Light touch.
50	Subcallosal fasciculus	Frontal cortex (Brodmann area 9).	Striate body.	Dorsal to caudate nucleus below radiation of corpus callosum.	
51	Tectospinal (Lowenthal)	Superior colliculus.	Spinal gray matter.	Ventromedial portion of ventral funiculus.	
52	Tegmental fasciculus central	Variable composition.		In reticular formation of medulla lateral to crossed vestibulospinal tract.	
53	Thalamic fasciculus	Fibers of brachium conjunctivum going to thalamus through tegmental field of Forel. Also fibers from globus pallidus.	Pallium. Thalamus.	Ventrally through Forel's field H1, between mammillothalamic tract and lenticular fasciculus.	
54	Vestibulofastigial	Vestibular nuclei and spinal nucleus of V.	Fastigial nucleus and vermian cortex.	Between restiform body and perivestricular gray matter; in juxtarestiform body.	
55	Vestibulo-flocculo-nodular	Cells of origin in vestibular ganglion (Scarpa).	Cortex of flocculus and nodulus of cerebellum.		Vestibular.
56	Vestibuloglobose	Vestibular nuclei and spinal nucleus of V.	Globose nucleus and vermian cortex.	Between restiform body and perivestricular gray matter in juxtarestiform body.	
57	Vestibulospinal, crossed, ventral	Medial, inferior and spinal vestibular nuclei.	Gray matter of cord.	Medial portion of ventral funiculus in sulcomarginal fasciculus of Marie.	Vestibular reflex.
58	Vestibulospinal, direct, lateral	Lateral vestibular nucleus.	Gray matter of cord.	Ventrolateral part of ventral funiculus and ventromedial portion of lateral funiculus.	Vestibular reflex.

284. ENCEPHALIC INDICES, EVOLUTIONARY SIGNIFICANCE: VERTEBRATES

Adapted from F. Tilney's "The Brain From Ape to Man," New York: Paul B. Hober, 1928.

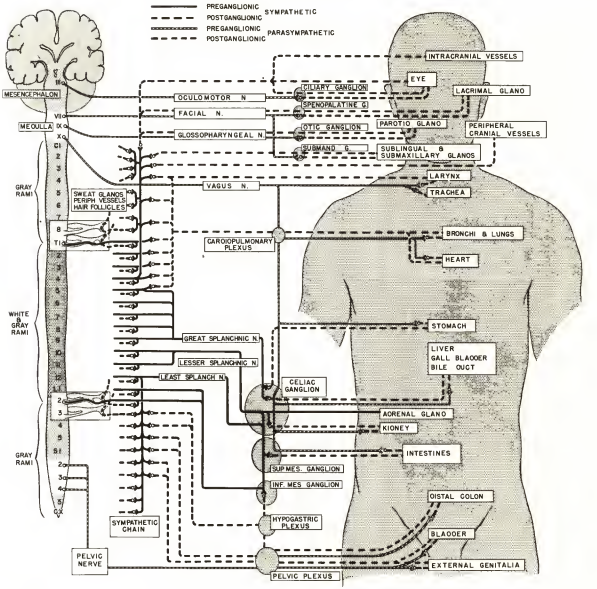
	Animal	Volume Index		Weight Index		
		Forebrain %	Midbrain %	Hindbrain %	Forebrain %	Midbrain %	Hindbrain %
	Index: 62 and Above			Hands, Fingers, Fingernails			
1	Man (Homo sapiens)	88	1	11	87	1	12
2	Gorilla (Gorilla gorilla)	84	2	14	84	2	14
3	Orangutan (Simia satyrus)	83	5	12	83	5	12
4	Monkey, Indian (Macaca rhesus)	83	2	15	84	2	14
5	Marmoset (Callithrix jacchus)	83	2	15	83	2	15
6	Gibbon (Hylobates hoolock)	82	2	16	82	2	16
	Index: 70 to 80			Paws, Hoofs, Claws			
7	Dog (Canis familiaris)	80	7	13	80	5	15
8	Cattle (Bos taurus)	80	2	18	80	2	18
9	Horse (Equus caballus)	80	2	18	80	2	18
10	Camel (Camelus bactrianus)	79	2	19	79	2	19
11	Cat (Felis catus)	77	6	17	75	4	21
12	Anteater, giant (Myrmecophaga sp)	75	6	19	73	5	22
13	Elephant (Elephas indicus)	72	2	26	71	2	27
14	Sloth, three-toed (Bradypus tridactylus)	70	10	20	70	10	20
	Index: 20 to 60			Wings, Fins, Paddles			
15	Ostrich (Rhea americana)	58	16	26	60	13	27
16	Turtle, soft-shelled (Aspidonectes ferox)	57	15	28	53	20	27
17	Frog (Rana sylvatica)				21	37	42
18	Codfish (Gadus morrbua)	20	40	40	20	40	40
19	Dogfish (Squalus acanthias)				23	27	50

285. THE BRAIN, PLANIMETRIC COEFFICIENTS: PRIMATES

Planimetric coefficient = ratio of planimetric measurement of the structure adapted to that of the total axis hemisection at a fixed magnification.

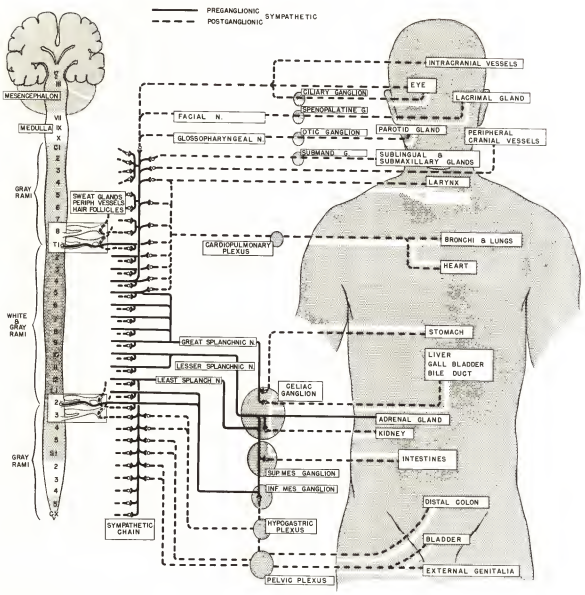
Adapted from F. Tilney's "The Brain From Ape to Man," New York: Paul B. Hober, 1928.

	Structure	Man	Gorilla	Chimpansee	Orang	Gibbon	Baboon	Macaque	Mycetes	Marmoset	Lemur	Tarsier
1	Pyramid	.183	.161	.172	.160	.138	.143	.147	.139	.064	.110	.032
2	Pontine nuclei	.550	.480	.400	.300	.200	.164	.150	.103	.095	.055	.057
3	Cerebral peduncle	.321	.187	.223	.110	.110	.190	.169	.144	.079	.086	.017
4	Inferior olive	.226	.186	.174	.172	.155	.125	.128	.120	.038	.060	.042
5	Nucleus dentatus	.176	.152	.136	.160	.134	.165	.155	.130	.077	.110	.059
6	Nucleus globosus	.023	.0095	.018	.015	.020	.023	.014	.032	.050	.032	.037
7	Red nucleus	.128	.096	.086	.087	.051	.060	.057	.081	.044	.012	.034
8	Superior cerebellar peduncle	.088	.047	.047	.064	.063	.044	.046	.036	.048	.033	.032
9	Inferior colliculus	.070	.111	.132	.131	.130	.155	.175	.182	.210	.223	.337
10	Superior colliculus	.104	.140	.125	.124	.132	.173	.158	.161	.154	.140	.230
11	Nucleus of Goll	.064	.086	.050	.048	.034	.086	.076	.131	.068	.041	.026
12	Nucleus of Burdach	.100	.081	.073	.093	.068	.065	.086	.113	.043	.049	.029
13	Nucleus of Dieters	.065	.072	.077	.054	.085	.060	.075	.114	.077	.082	.180
14	Nucleus of Schwalbe	.075	.070	.080	.055	.092	.095	.087	.090	.060	.045	.062



	Division	Preganglionic Neurons	Outflow	Ganglia	Distribution	Effects of Increased Activity
1	S	Intermediolateral column in spinal cord, C 8 to L 3.	Thoracic, lumbar nerves.	Sympathetic trunk.	Thoracic viscera, cardiovascular system, peripheral smooth muscle, sweat glands.	Inhibition of bronchial and gastrointestinal musculature; cardiac acceleration, increased vascular tonus, activation of peripheral smooth muscle and sweat glands.
				Abdominal and pelvic plexuses.	Abdominal, pelvic viscera and blood vessels.	Inhibition of visceral musculature, increased splanchnic vascular tonus.
2	P	Edinger-Westphal nucleus.	Cranial nerve III.	Ciliary.	Intraocular muscles.	Activation of ciliary muscle and circular muscle of iris.
3		Salivatory nuclei.	Cranial nerves VII, IX.	Sphenopalatine, otic, submandibular lingual.	Smooth muscle and glands.	Activation of salivary glands and glands in mucous membranes.
4		Vagus nucleus.	Cranial nerves X, XI.	Cardiac, pulmonary, enteric	Heart, some blood vessels, visceral musculature, glands.	Cardiac inhibition; activation of bronchial and gastrointestinal musculature and glands.
5		Visceral nuclei in sacral segments of spinal cord.	S2, S3, S4.	Pelvic.	Pelvic viscera.	Activation of pelvic visceral musculature; control of bladder sphincter.
6	E[1]	Vagus nuclei.	Vagus nerves.	Enteric.	E musculature, glands.	Activation of E musculature and glands.
7	E[1]	Visceral nuclei in sacral segments of spinal cord.	S2, S3, S4.	Enteric.	Musculature and glands of colon and rectum.	Activation of musculature and glands of colon and rectum.

[1] Actually a subdivision of P.



SC = sympathetic chain; WRC = white ramus communicans.

	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
				Cell Body	Pathway	Cell Body	Pathway	
1	Eye	Man	Dilator pupillae.	T1,2,3(Oc.C8&T4).	WRC, SC.	Superior cervical ganglion.	Carotid plexus → short and long ciliary nerve.	Dilatation.
2				C8, T1,2.				
3		Cat					Superior carotid nerve; ophthalmic nerve; ciliary nerve.	
4		Man	Muscle orbitalis.	T1, 2, 3.				
5			Bulbar, conjunctival vessels.	T2, 3, 4, 5.			Carotid plexus; ophthalmic nerve.	(?).
6		Cat	Nictitating membrane.	T1, 2, 3, 4.			Superior carotid nerve; ophthalmic nerve; ciliary nerve.	Vaso-constriction. Retraction.
7	Lacrimal gland	Man	Blood vessels.	T1, 2, 3.	WRC, SC.	Superior cervical ganglion.	Internal carotid plexus and branches.	Vaso-constriction.

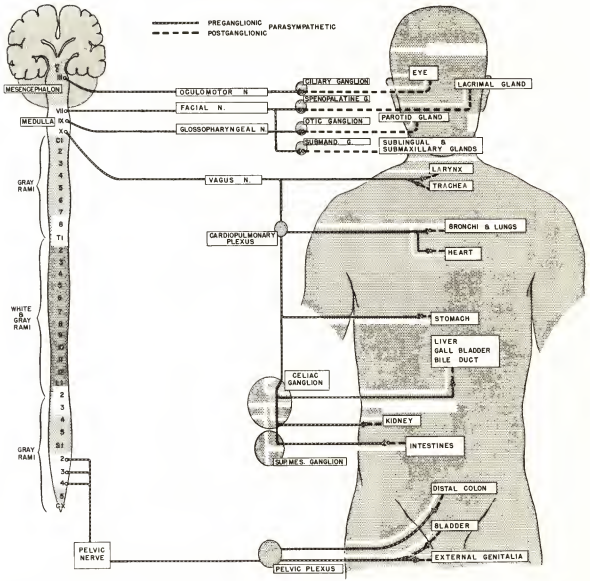
SC = sympathetic chain; WRC = white ramus communicans.

	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
				Cell Body	Pathway	Cell Body	Pathway	
8	Heart	Man	Mostly ventricular muscle, some auricular.	T1, 2, 3, 4, 5.	WRC, SC.	Superior cervical ganglion; middle cervical ganglion; inferior cervical ganglion; stellate ganglion; upper 2 or 3 thoracic ganglia.	Superior cervical cardiac nerve, middle cervical cardiac nerve; inferior cervical cardiac nerve; cardiac plexus.	Augmentation and acceleration.
9		Dog	Mostly ventricular muscle, some auricular.	T1-4.	WRC, SC.	Middle cervical ganglion.	Middle cardio-sympathetic nerve (accelerator nerve).	Augmentation and acceleration.
10		Cat		T1, 2-4, 5.		Stellate ganglion.	Cardio-accelerator nerve; coronary arteries; ventricles.	
11	Coronary artery	Man	Smooth muscle.	T1, 3, 4, 5.	WRC, SC.	Superior cervical ganglion; middle cervical ganglion, inferior cervical ganglion; stellate ganglion; and upper 2 or 3 thoracic ganglia.	Superior cervical cardiac nerve, middle cervical cardiac nerve; inferior cervical cardiac nerve; cardiac plexus.	Dilatation.
12	Blood vessels	Man	Meningeal arteries.	T1, 2.	WRC, SC.	Superior cervical ganglion.	External carotid plexus; middle meningeal artery.	Vasoconstriction.
13			Cerebral arteries.				Internal carotid plexus and branches.	
14			Vertebral system of brain.			Stellate ganglion.	Vertebral plexus.	
15	Blood vessels, sweat glands, and pilo-erection muscles	Man	Head, neck.	T1,2,3(Oc.C8&T4).	WRC, SC.	Superior cervical ganglion.	Gray rami to cervical plexus.	Vasoconstriction, sweating, pilo-erection.
16			Upper limb.	T1, 2-9, 10.		Superior cervical ganglion; middle cervical ganglion, inferior cervical ganglion; stellate ganglion.	Gray rami; brachial plexus and subclavian artery.	
17			Thoracic and upper abdominal wall.	T2-10.		Middle cervical ganglion; inferior cervical ganglion; stellate ganglion; upper thoracic ganglia.	Gray rami, intercostal nerves.	Sweating, pilo-erection.
18			Lower limb, trunk.	T6-L2.		Lumbar 1-4; sacral 1-3.	Gray rami, lumbar and sacral nerves.	
19	Adrenal medulla	Man	Cells of medulla.	T5-9, 10-L1, 2.	WRC, SC. (splanchnic).	Cells of adrenal medulla.	No postganglionic pathway.	Secretion.
20	Spleen	Dog	Smooth muscle of capsule, trabeculae and artery.	T5, 6-8, 9-12.	WRC, SC (splanchnic).	Thoracic ganglia 6-11, and cellac plexus.	Splenic nerve; celiac plexus; plexus on splenic artery.	Splenovasoconstriction.
21			Splenic veins.	T5.		Stellate ganglion.	Gray rami; phrenic nerve; plexus on splenic artery.	Vasoconstriction(?).
22	Lung	Man	Trachea, bronchi	T2-4.	WRC, SC.	Inferior cervical, stellate, and upper 4 thoracic ganglia.	Cardiac accelerstor -- deep cardiac and pulmonary plexus.	Tracheal, bronchial, dilatation.
23			Blood vessels.					Vasoconstriction.
24		Cat	Trachea, bronchi, blood vessels.	T3-7.				Tracheal, bronchial dilatations.
25	Submaxillary, sublingual glands	Man	Gland, vessels.	T1, 2, 3.	WRC, SC.	Superior cervical ganglion.	External carotid plexus and branches.	Vasoconstriction; weak secretion.
26	Parotid gland	Man	Gland, vessels.	T1, 2, 3.	WRC, SC.	Superior cervical ganglion.	External carotid plexus and branches.	Vasoconstriction; weak secretion(?).
27	Lower esophagus	Man	Smooth muscle.	T1-3, 4-6.	WRC, SC (great splanchnic).	Inferior or stellate, upper thoracic, celiac ganglia.	Esophageal rami, aortic plexus; left gastric, phrenic nerves.	Inhibits peristalsis.
28	Cardiac sphincter	Man	Smooth muscle.	T1-3, 4-6.	WRC, SC (great splanchnic).	Inferior or stellate, upper thoracic, celiac ganglia.	Esophageal rami, aortic plexus; left gastric, phrenic nerves.	Contraction.
29	Stomach	Man	Smooth muscle, gland.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac ganglion.	Accompanies gastric artery.	Inhibits peristalsis.
30			Pyloric sphincter.					Contraction.
31			Blood vessels.					Vasoconstriction.
32	Pancreas	Man	Gland.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac ganglion.	Accompanies pancreatic artery.	Secretion(?).
33			Blood vessels.					Vasoconstriction.
34	Liver	Man	Blood vessels.	T5, 6, 7-10.	WRC, SC (splanchnic).	Celiac ganglion.	Periarterial plexus of hypogastric artery.	Vasoconstriction.

Part II: SYMPATHETIC CONNECTIONS (Concluded)

SC = sympathetic chain; WRC = white ramus communicans.

	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
				Cell Body	Pathway	Cell Body	Pathway	
35	Gallbladder	Man	Smooth muscle	T5, 6, 7-10.	WRC, SC (splanchnic).	Celiac ganglion.	Periarterial plexus of hepatic artery.	Relaxation.
36			Sphincter of common bile duct.				Periarterial plexuses.	Contraction.
37	Small intestine, upper colon	Man	Smooth muscle, glands.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac and superior mesenteric ganglia.	Celiac and superior mesenteric rami.	Inhibitory.
38	Ileocecal sphincter	Man	Blood vessels, sphincter muscle.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac and superior mesenteric ganglia.	Celiac and superior mesenteric rami.	Vasoconstriction and contraction.
39	Lower colon, rectum	Man	Smooth muscle.	T12, L1, 2, 3.	WRC, SC (lumbar splanchnic).	Inferior mesenteric ganglion.	Plexus of inferior mesenteric artery.	Contraction, inhibition.
40			Blood vessels.					Vasoconstriction.
41	Internal sphincter ani	Man	Blood vessels, sphincter muscle.	L1, 2, 3.	WRC, SC (lumbar splanchnic).	Aortic ganglion.	Aortic and hypogastric plexus.	Vasoconstriction and contraction.
42	Kidney	Man	Blood vessels, smooth muscle.	T5-L2.	WRC, SC (splanchnic).	Aortic or renal ganglion.	Renal plexus.	Vasomotor changes.
43	Ureter	Man	Blood vessels, smooth muscle.	T5-12.	WRC, SC (splanchnic).	Aortic or renal ganglion.	Renal plexus and hypogastric nerve.	Rhythmic contraction.
44	Bladder	Man	Detrussor vesicae.	L1-3.	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus, intramural ganglia.	Intramural plexus.	Relaxation.
45			Sphincter vesicae.			Vesical plexus.		Constriction for ejaculation.
46	Urethra	Man	Compressor urethrae.	L1-3.	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus; intramural ganglia.	Prostatic plexus.	Contraction.
47	Prostate	Man	Smooth muscle.	T12-L2	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus, prostatic plexus.	Prostatic plexus.	Contraction; ejaculation.
48	Seminal vesicles, vas deferens	Man	Smooth muscle.	T12-L2	WRC, SC (hypogastric nerve; pelvic plexus).	Vesical plexus.	Plexuses of seminal vesicles and vas deferens.	Contraction; ejaculation.
49	Testes	Man	Blood vessels.	T6-12.	WRC, SC.	Probably lower thoracic ganglia of sympathetic chain.	Splanchnic nerve, aortic and renal plexuses, spermatic plexus.	Vasoconstriction.
50	Corpora cavernosa	Man	Blood vessels.	T12-L2.	WRC, SC.	Lumbar, sacral ganglia of sympathetic chain.	Hypogastric plexus, prostatic plexus, cavernous plexus.	Vasoconstriction.
51	Clitoris, labia minora	Man	Blood vessels.	T12-L2.	WRC, SC.	Lumbar, sacral ganglia of sympathetic chain.	Hypogastric plexus, vaginal plexus, cavernous plexus.	Vasoconstriction.
52	Vagina	Man	Smooth muscle.	T12-L2.	WRC, SC (hypogastric nerve).	Pelvic plexus, uterovaginal plexus.	Vaginal plexus.	Contraction.
53	Uterus (nonpregnant)	Dog	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, uterovaginal plexus.	Uterine plexus.	Relaxes.
54	Uterus (pregnant)	Dog	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, uterovaginal plexus.	Uterine plexus.	Contracts.
55	Uterus (nonpregnant)	Cat	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, uterovaginal plexus.	Uterine plexus.	Contracts.
56	Uterine tube (lower)	Dog	Smooth muscle	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, uterovaginal plexus.	Uterine plexus.	Contracts.
57	Ovary, upper uterine tube	Man	Vascular bed, stroma.	T6-12.	WRC, SC	Probably lower thoracic ganglia of sympathetic chain.	Splanchnic nerve; aortic, renal plexuses; ovarian plexus.	Vasoconstriction, contraction.



	Organ	Species	Effector	Preganglionic Neurone: Cell Body	Preganglionic Neurone: Pathway	Postganglionic Neurone	Actioo
1	Eye	Man	Sphincter pupillae.	Visceral oculo-motor nucleus of Edinger-Westphal.	Oculomotor nerve; motor root; ciliary ganglion.	Ciliary ganglioo -- short ciliary nerve.	Coostriction of pupil.
2			Ciliary muscle.				Accommodation.
3		Bird	Sphincter pupillae, ciliary muscle (striated).	Visceral oculo-motor ouclcus of Edinger-Westphal (very large).		Ciliary ganglion -- short ciliary nerve (all fibers very large).	Constriction of pupil, accom-modatioo (rapid).
4	Lacrimal gland	Man	Gland cells.	Nucleus saliva-torius superior.	Nervus intermedius; great superficial petrosal nerve; vidian nerve.	Sphenal-palatine ganglion; zygomatic nerve; lacrimal nerve.	Secretioo.
5	Heart	Man	Sino-atrial node; strio-ventricu-lar node, con-duction system; auricular muscle.	Dorsal motor nu-cleus of vagus.	Superior, inferior, thoracic cardiac rami of vagus.	Intrinsic cardiac ganglia to wall of strium and auricle.	Inhibitory; de-creases heart rate.
6		Dog			Right cardiovagal nerve; accelerster nerve; deep cardiac plexus. Left car-diovagal nerve; deep cardiac plexus.	Intrinsic ganglia on or above corooary sulcus in strium.	

Part III: PARASYMPATHETIC CONNECTIONS (Concluded)

	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone	Action
				Cell Body	Pathway		
7	Coronary artery	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Superior, inferior, thoracic cardiac rami of vagus.	Intrinsic cardiac ganglia, adventitia, small branches of coronary artery.	Constriction.
8	Blood vessels	Man	Smooth muscle.	Demonstrated only for brain, meninges, face, and most glands.			Vaso-constriction.
9	Adrenal medulla	Man	None demonstrated.				
10	Spleen	Man	None demonstrated.				
11	Lung and trachea	Man	Smooth muscle of trachea, bronchial tree.	Dorsal motor nucleus of vagus.	Vagal branches; anterior, posterior pulmonary; deep cardiac plexuses.	Intramural tracheal, bronchial ganglia.	Tracheal, bronchial constriction
12			Tracheal, bronchial glands.				Secretion.
13	Submaxillary, sublingual glands	Man	Gland cells, blood vessels.	Nucleus salivatorius superior.	Nervus intermedius, 7th nerve; chorda-tympani; lingual nerve.	Submaxillary ganglion; submaxillary, sublingual branches.	Secretion, vasodilatation.
14	Parotid gland	Man	Gland cells, blood vessels.	Nucleus salivatorius inferior.	9th nerve; tympanic nerve; lesser superficial petrosal nerve; lingual nerve.	Otic ganglion; auriculotemporal nerve.	Secretion, vasodilatation.
15	Lower esophagus	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; esophageal plexus.	Myenteric ganglianated plexus.	Increases tonus, peristalsis.
16			Cardiac sphincter.				Relaxation.
17	Stomach	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; gastric branches.	Myenteric ganglionated plexus.	Contraction; increases tonus, peristalsis secretion.
18			Gastric glands.			Submucosal ganglionated plexus.	
19	Pyloric sphincter	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; gastric branches.	Myenteric ganglionated plexus.	Diminishes tonus, inhibitory.
20	Pancreas	Man	Gland cells, blood vessels.	Dorsal motor nucleus of vagus.	Vagus nerve; pancreatic branches.	Pancreatic ganglia.	Secretion, vasodilatation.
21	Liver	Man	Hepatic cells.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic branches.	Intramurel ganglia.	Secretion (?).
22	Gallbladder	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Emptying of gallbladder.
23	Biliary tree	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Elevates pressure of bile ducts.
24	Sphincter of common bile duct	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Relaxation.
25	Small intestine	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Contraction, peristalsis.
26			Gland.			Submucosal ganglionated plexus.	Secretion.
27	Ileocecal sphincter	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Inhibitory, diminishes tonus.
28	Upper colon	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Contraction, peristalsis.
29			Glands.			Submucosal ganglionated plexus.	Secretion.
30	Lower colon	Man	Smooth muscle	S2, 3, 4.	Pelvic nerve; hypogastric nerve -- inferior mesenteric plexus.	Myenteric ganglionated plexus.	Contraction, vasodilatation, peristalsis, secretion.
31			Glands.			Submucosal ganglionated plexus.	
32			Internal sphincter ani.			Myenteric ganglionated plexus.	Inhibition; vasodilatation.
33	Kidney	Man	None demonstrated.				
34	Ureter	Man	None demonstrated.				
35	Bladder	Man	Detrussor vesicae.	S2, 3, 4.	Pelvic nerve (nerve eregentes).	Pelvic plexus; vesical, intramural ganglia.	Contraction.
36			Sphincter vesicae.				Relaxation.
37	Urethra	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus; prostatic plexus.	Control of sphincter.
38	Prostate	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus; prostatic plexus.	(?).
39	Seminal vesicles and vas deferens	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus.	(?).
40	Testes	Man	None demonstrated.				
41	Corpora cavernosa	Man	Erectile tissue.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; cavernous plexus.	Vasodilatation; erection.
42	Clitoris and labia minora	Man	Erectile tissue.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; utero-vaginal plexus.	Vasodilatation; erection.
43	Vagina	Man	None demonstrated.				
44	Ovary	Cat	None demonstrated.				
45	Uterus	Monkey	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Probably uterocervical ganglion.	Motility (?).
46	Cervix of uterus	Man	Smooth muscle.				
47	Uterine tube	Man	None demonstrated.				
48	Ovary	Man	None demonstrated.				
49	Thyroid gland	Man	No true secretory fibers present.				
50	Face	Man	Blood vessels.	Nucleus salivatorius superior(?)	Nervus intermedius, 7th nerve.	(?).	Vasodilation; blushing.

	Ganglia	Class.	Location	Preganglionic Connections	Postganglionic Distribution
1	Accessory	S	In relation to ventral nerve roots, communicating rami and S roots.	Ventral nerve roots.	Primary ventral rami of spinal nerves, visceral nerves.
2	Aortico-renal	S	Root of renal artery.	Splanchnic nerves.	Renal and aortic plexuses.
3	Bronchial	P	Bronchial plexuses.	Vagus nerves.	Bronchial musculature and glands.
4	Cardiac	P	Cardiac plexus.	Vagus nerves.	Heart, coronary vessels, pulmonary plexuses.
5	Celiac	S	Celiac plexus.	Splanchnic nerves.	Abdominal viscera and blood vessels.
6	Cervical sympathetic, inferior	S	Sympathetic trunk, level of vertebra T 1.	Thoracic nerves.	Brachial plexus, inferior cardiac nerve, common carotid plexus, vertebral nerve.
7	Intermediate	S	Sympathetic trunk, level of vertebra C 8.	Thoracic nerves.	Ansa subclavia, inferior cardiac nerve, sympathetic roots of nerves C 6, 7, 8.
8	Middle	S	Symp. trunk, level of vertebra C 6.	Thoracic nerves.	Middle cardiac nerve, S roots of nerves C 5, 6.
9	Superior	S	Sympathetic trunk, 2nd, 3rd, 4th cervical vertebrae.	Thoracic nerves.	Internal, external carotid nerves, sympathetic roots of nerves C 1-3, superior cervical cardiac nerves.
10	Cervical of uterus	P, S	Pelvic plexus adjacent to cervix of uterus.	Pelvic nerves, hypogastric plexus.	Uterus and vagina.
11	Ciliary	P	Orbit, between optic nerve and lateral rectus muscle.	Oculomotor.	Short ciliary nerves.
12	Enteric	E	Wall of enteric canal.	Vagus and sacral nerves.	Enteric muscles and glands.
13	Impar (or coccygeal)	S	Ventral surface of coccyx.	Lumbar spinal nerves.	Caudal spinal nerves.
14	Lingual	P	Posterior portion of tongue.	Facial and chorda tympani.	Lingual glands.
15	Mediastinal	S	Posterior mediastinum in relation to splanchnic nerves.	Splanchnic nerves.	Celiac plexus.
16	Mesenteric, inferior	S	Adjacent to inferior mesenteric artery.	Splanchnic nerves.	Inferior mesenteric and hypogastric plexuses.
17	, superior	S	Adjacent to root of superior mesenteric artery.	Splanchnic nerves.	Superior mesenteric, aortic, and renal plexus.
18	Myenteric	E	Between longitudinal and circular enteric muscle layers.	Vagus and pelvic nerves.	Enteric muscles.
19	Otic	P	Medial to mandibular nerve, just below foramen ovale.	Glossopharyngeal nerve	Supplies auriculo-temporal nerve with fibers to parotid gland.
20	Pelvic	P, S	Adjacent to pelvic viscera.	Pelvic nerves, hypogastric plexus.	Pelvic viscera and blood vessels.
21	Pulmonary	P	Pulmonary plexuses.	Vagus nerves.	Bronchial plexuses.
22	Semilunar [1]	S	Celiac plexus.	Splanchnic nerves.	Abdominal viscera and blood vessels.
23	Sphenopalatine [1]	P	Pterygopalatine fossa.	Facial nerve.	Pharyngeal, palatine, nasal, and orbital nerves.
24	Submaxillary	P	Between lingual nerve and duct of submaxillary gland.	Chorda tympani (through facial).	Submaxillary, sublingual, and lingual glands.
25	Submucous	E	Submucous of enteric canal.	Vagus and pelvic nerves.	Enteric muscles and glands.
26	Sympathetic trunk	S	Ventrolateral to vertebral column.	Spinal nerves T 1-L 3, 3.	Sympathetic roots of spinal nerves, cephalic sympathetic, cardiac and splanchnic nerves.
27	Terminale	P	Adjacent to olfactory tract.	Nervus terminalis.	Anterior cerebral artery, vomero nasal organ, nasal mucosa.
28	Tracheal	P	Tracheal wall.	Vagus nerves.	Tracheal and bronchial plexus.

[1] Supplied by greater superficial petrosal through facial nerve.

Part V: PLEXUSES

	Plexus	Class.	Origin	Distribution
1	Adrenal	S	Celiac plexus.	Adrenal artery and gland.
2	Aortic	S	Sympathetic trunks.	Aorta and proximal portions of its branches.
3	Cardiac, superficial	P, S	Cervical and thoracic sympathetic cardiac nerves, branches of vagus nerves.	Heart, coronary vessels, anterior pulmonary plexuses.
4	Cardiac, deep	P, S	Right superior, middle and inferior cervical and thoracic sympathetic cardiac nerves, all cardiac branches of right vagus, left middle and inferior cervical and thoracic cardiac nerves, superior cervical and cardiac branches of left vagus.	Heart, coronary vessels, anterior pulmonary plexuses.
5	Carotid, common	S	Sympathetic trunk.	Common carotid artery.
6	Carotid, external	S	Superior cervical ganglion, common carotid plexus.	External carotid artery and its branches.
7	Carotid, internal	S	Superior cervical ganglion, common carotid plexus.	Internal carotid artery and its branches, carotictympanic and deep petrosal nerves, cavernous plexus.
8	Cavernous	S	Internal carotid plexus.	Cavernous sinus, oculomotor, trochlear and ophthalmic nerves, ciliary ganglion, hypophysis.
9	Celiac	S	Intrinsic ganglia, splanchnic nerves.	Celiac artery and its branches.
10	Colic	S	Inferior mesenteric plexus.	Colon.
11	Duodenal	S	Superior mesenteric and pancreatic plexuses.	Duodenum and pancreas.
12	Enteric	E	Vagus, sacral nerves, intrinsic ganglia, esophageal, celiac, mesenteric and pelvic plexuses.	Enteric canal.
13	External maxillary	S	External carotid plexus.	External maxillary artery, submaxillary and otic ganglia.
14	Hepatic	P, S	Vagus nerves and celiac plexus.	Biliary system, hepatic blood vessels.
15	Hypogastric	S	Celiac, aortic, inferior mesenteric plexuses.	Pelvic plexuses.
16	Spermatic	S	Aortic and renal plexuses.	Spermatic artery, spermatic cord, testis.
17	Mesenteric, inferior	S	Celiac plexus, lumbar splanchnic nerves.	Inferior mesenteric artery and its branches.
18	Mesenteric, superior	S	Celiac plexus.	Superior mesenteric artery and its branches.
19	Meningeal, middle	S	External carotid plexus.	Middle meningeal artery.
20	Ovarian	S	Aortic and renal plexuses.	Ovarian artery, ovary.
21	Pancreatic	P, S	Vagus nerves, intrinsic ganglia, sympathetic trunks.	Pancreas, pancreatic ducts and vessels.
22	Pelvic	P, S	Hypogastric plexus, pelvic nerves, intrinsic ganglia.	Pelvic viscera and blood vessels.
23	Pulmonary	P, S	Vagus nerves, intrinsic ganglia, sympathetic trunks.	Bronchial plexuses, pulmonary vessels.
24	Phrenic	S	Celiac plexus, lesser and least splanchnic nerves.	Renal blood vessels, supplies adrenal gland, diaphragm, esophagus, inferior cava.
25	Prostatic	P, S	Pelvic plexus.	Prostate gland.
26	Renal	S	Celiac plexus, splanchnic nerves.	Renal blood vessels.
27	Sigmoid	S	Inferior mesenteric plexus.	Sigmoid colon.
28	Splenic	S	Celiac plexus.	Spleen, pancreas, stomach.
29	Tympanic	P, S	Internal carotid nerve, rämus from petrosal ganglion.	Tympanum, mastoid cells, auditory tube.
30	Uterine	P, S	Pelvic plexus.	Uterus.
31	Vaginal	P, S	Pelvic plexus.	Vagina.
32	Vesical	P, S	Pelvic plexus.	Urinary bladder.

Cranial nerves are indicated by Roman numerals; spinal nerves by Arabic numerals and literal designation as follows: C = cervical; Th = thoracic; L = lumbar; S = sacral; Coc = coccygeal. Nerves listed are those considered most important; a complete atlas is not intended.

	Nerve(s)	Distribution
	Cranial Nerves	
1	Olfactory (I)	Nasal mucous membrane.
2	Optic (II)	Retina.
3	Oculomotor (III)	Levator palpebrae, recti (medial, superior and inferior) and inferior oblique muscles of eye. Sphincter pupillae and ciliary muscles via ciliary ganglion and short ciliary nerves[1].
4	Trochlear (IV)	Superior oblique muscle of eye.
	Trigeminal (V)	
	Ophthalmic division	
5	Tentorial	Tentorium and dura of anterior cranial fossa.
	Frontal	
6	Supraorbital	Skin of upper eyelid, forehead, anterior scalp, mucosa of frontal sinus.
7	Supratrochlear	Medial forehead, root of nose, medial commissure of eye.
8	Lacrimal	Lacrimal gland, conjunctiva, lateral commissure of eye.
	Nasociliary	
9	Long ciliary	Intraocular structures (sensory).
10	Posterior ethmoidal	Mucosa of posterior ethmoid cells and of sphenoid sinus.
11	Anterior ethmoidal	Mucosa of upper and anterior nasal septum, lateral wall of nasal cavity, skin of lower bridge and tip of nose.
12	Infratrochlear	Root and upper bridge of nose, conjunctiva, skin of eyelids, lacrimal sac.
	Maxillary division	
13	Middle meningeal	Dura of anterior cranial fossa.
	Zygomatic	
14	Zygomaticofacial	Skin over zygomatic bone.
15	Zygomaticotemporal	Skin of anterior temple.
16	Posterior superior alveolar	Upper molar teeth and gum, mucosa of maxillary sinus.
17	Superior dental	Upper molar teeth.
18	Infraorbital	Skin of anterior cheek, side of nostril, skin and conjunctiva of lower eyelid.
19	Middle and ant. sup. alveolar	Upper teeth (except molars), mucosa of maxillary sinus.
	Sphenopalatine nerves via ganglion	
20	Post. sup. lat. nasal	Mucosa of superior and middle nasal conchae.
21	Post. sup. medial nasal	Mucosa of posterior part of nasal septum, post. ethmoid sinus.
22	Post. inferior nasal	Mucosa of middle and inferior nasal conchae.
23	Palatines	Soft palate and tonsil via greater petrosal nerve and Vidian nerve.
	Mandibular division	
24	Spinous	Dura mater of middle cranial fossa.
	Masticator	
25	Masseter	Masseter muscle.
26	Deep temporal	Temporal muscle.
27	Pterygoid ext. and int.	Pterygoid muscles.
28	Buccinator	Skin of mid-cheek, mucosa of mouth.
29	Auriculotemporal	Skin of temple, superior part of ear, external acoustic meatus, tympanic membrane.
30	Lingual	Mucosa of anterior 2/3 of tongue, lateral wall and floor of mouth.
	Inferior alveolar	
31	Mylohyoid	Mylohyoid muscle, anterior belly of digastric muscle.
32	Dental, inferior	Lower teeth.
33	Mental and inf. labial	Skin of chin, mucosa of lower lip.
34	Abducens (VI)	Lateral rectus muscle of eye.
35	Facial (VII)	Posterior auricular muscle, occipital belly of epicranius muscle, posterior belly of digastric muscle, stylohyoid, platysma and buccinator muscles, lip, chin and nose muscles, orbicularis oculi muscle, stapedius muscle.
	Nervus intermedius[2]	
36	Greater superficial petrosal	Lacrimal gland via vidian nerve, sphenopalatine ganglion, anastomotic zygomaticotemporal nerve and lacrimal nerve[1], from soft palate and tonsil via posterior palatine nerve and sphenopalatine ganglion.

	Nerve(s)	Distribution
	Nerves of Shoulder Girdle and Upper Extremity (concluded)	
78	Median (C6-Th1)	Intrinsic muscles of hand (abductor brevis, opponens and flexor brevis of thumb, medial two lumbricals), pronators quadratus and teres, long forearm flexors (of hand and fingers, except flexor profundus IV and V), skin of radial half of palm and fingers I-IV.
79	Ulnar (C8 and Th1)	Intrinsic muscles of hand (adductor pollicis, short muscles of little finger, all interossei, lateral two lumbricals), long forearm flexors (flexor carpi ulnaris, flexor profundus of fingers IV and V), skin of ulnar half of hand and of fingers IV and V.
80	Radial (C5-Th1)	Extensor muscles of forearm, brachioradialis and extensor carpi, radialis longus.
81	Posterior interosseous	Supinator, extensor carpi radialis brevis, extensor muscles to hand and fingers, intrinsic extensor muscles of thumb.
82	Post. cutaneous br arm	Skin of back of arm.
83	Lower lat. cutaneous of arm	Skin of lateral side of arm.
84	Post. cutaneous of forearm	Skin of back of forearm.
85	Dorsal digital	Skin of dorsal aspect of hand at base of thumb, index and middle fingers, and contiguous proximal surface of thumb, index and middle fingers.
86	Medial cutaneous of arm (C8, Th1)	Skio of medial side of arm.
87	Medial cutaneous of forearm (C8 and Th1)	Skin of medial side of forearm.
	Nerves of Trunk, Thorax and Abdomen	
88	Intercostobrachial (Th1-Th3)	Skin of axilla and medial side of arm.
89	Thoracic (Th2-Th12) (intercostal and post. rami)	Intercostal: skin of thorax and abdomen, intercostal muscles; post rami: skin of trunk, longitudinal back muscles.
90	Thoracic (Th7-Th12)	Oblique, transverse and rectus abdominal muscles.
91	Lumbar, sacral and coccygeal (posterior rami)	Skin of lower back from spinous process L1 through coccyx, deep muscles of lower back.
	Nerves of Abdomen, Pelvic Region, Perineum, Bladder and Genitals	
92	Iliohypogastric (L1)	Skin above pubis and lateral gluteal region.
93	Ilioinguinal (L1)	Skin of pubis, inguinal region and upper 1/3 of penis.
94	Genitofemoral (L1 and L2)	Cremaster muscle, skin of upper scrotum and groin.
95	Superior gluteal (L4-S1)	Gluteus medius and minimus muscles.
96	Inferior gluteal (L5-S2)	Gluteus maximus muscle.
	Pudendal plexus (S2-S4)	
97	Middle hemorrhoidal	Lower colon via hypogastric plexus.
98	Pelvic (erigentes)	Detrusor muscle and internal sphincter muscle of bladder via vesical plexus, rectum via pelvic plexus.
99	Muscular (S4)	Levator ani and coccygeus muscles.
	Pudendal (S2-S4)	
100	Inferior hemorrhoidal	External sphincter of anus, skin around anus.
101	Perineal	External sphincter of anus, transverse perineal and bulbocavernosus muscles, skin of lower scrotum (labia majorum), mucosa of urethra, bulb and corpus spongiosus of penis.
102	Dorsal, of penis (of clitoris)	Skin of lower 2/3 of penis (clitoris), crus and corpus cavernosus of penis (clitoris).
103	Coccygeal plexus (S5-Coc 1)	Skin over coccyx (anococcygeal nerves).
	Nerves of Lower Extremity	
104	Lat. cutaneous of thigh (L2 and L3)	Skin of lateral side of thigh.
105	Post. cutaneous of thigh (S1-S3)	Skin of back of thigh and lower buttock.
106	Femoral (L2-L4)	Muscles of front of thigh.
107	Ant. cutaneous of thigh	Skin of front of thigh and medial side of knee.
108	Saphenous	Skin of medial side of knee and ankle.
109	Obturator (L2-L4)	Adductor muscles of thigh, obturator externus skin of medial side of knee.
110	Sciatic (L4-S3) Nerve to hamstring muscles (L4-S3)	Muscles of back of thigh.

37	Chorda tympani[3]	Submaxillary and sublingual glands via lingual nerve and submaxillary ganglion[4], anterior 2/3 of tongue.
	Acoustic (VIII)	
38	Auditory (Cochlear)	Organ of Corti in cochlea.
39	Vestibular	Macula of utricle in vestibule, cristae of ampullae in semi-circular canals.
	Glossopharyngeal (IX)	
40	Tympanic	Tympanic cavity, tympanic membrane, mastoid air cells.
41	Pharyngeal	Mucosa of pharynx (from level of eustachian tube to the epiglottis).
42	Stylopharyngeal	Stylopharyngeus muscle.
43	Tonsillar	Fauces, including tonsil.
44	Lingual	Posterior 1/3 of tongue, posterior rim of soft palate, uvula.
45	Parotid	Parotid gland via nerve to digastric muscle, facial nerve, anastomotic nerve, otic ganglion and auriculo-temporal nerve[1].
	Vagus (X)	
46	Meningeal	Dura mater of floor of posterior cranial fossa.
47	Auricular	External acoustic meatus, tympanic membrane, skin between ear and mastoid.
48	Pharyngeal	Pharyngeal and palatine muscles, mucosa of pharynx.
49	Superior laryngeal	Inferior pharyngeal constrictor and cricothyroid muscles, mucosa of larynx, epiglottis.
50	Sup. and inf. cardiac[1]	Heart via cardiac plexuses.
51	Recurrent laryngeal	Intrinsic muscles of larynx (inferior laryngeal nerve) except cricothyroid, heart via cardiac plexus, trachea and esophagus via periaortic plexus.
52	Bronchial[1]	Bronchi via pulmonary plexuses.
53	Esophageal[1]	Esophageal muscle and mucosa via esophageal plexus.
	Abdominal[1]	
54	Anterior branch (right)	Anterior surface and lesser curvature of stomach and pylorus and duodenum via gastric plexuses, liver via celiac and hepatic plexuses.
55	Posterior branch (left)	Posterior surface of stomach (posterior gastric nerve), small intestine and ascending colon via superior mesenteric plexus, spleen and kidney via celiac, splenic and renal plexuses.
56	Spinal accessory (XI)	Sternocleidomastoid and trapezius muscles.
57	Hypoglossal (XII)	Intrinsic and extrinsic tongue muscles.
	Cervical Nerves	
	Sensory	
58	Greater occipital (C2)	Scalp of medial half of back of head.
59	Lesser occipital (C2 and C3)	Scalp of lateral half of back of head.
60	Great auricular (C2 and C3)	Most of ear, skin at angle of jaw.
61	Anterior cutaneous of neck (C2 and C3)	Skin of front of neck.
62	Supraclavicular (C3 and C4)	Skin over shoulder girdle and upper 3 ribs.
	Motor	
63	Roots C1-C3	Infrahyoid muscles (via ansa hypoglossi), occipito-vertebral muscles.
64	Roots C2 and C3	Sternocleidomastoid muscle.
65	Roots C3 and C4	Levator scapulae and trapezius muscles.
66	Roots C3-C7	Longus colli and scalenus muscles.
67	Phrenic (C3-C5)	Diaphragm.
	Nerves of Shoulder Girdle and Upper Extremity	
68	Long thoracic (C5-C7)	Serratus anterior muscle.
69	Anterior thoracis (C5-Th1)	Pectoralis major and minor muscles.
70	Dorsal scapular (C5)	Levator scapulae and rhomboid major and minor muscles.
71	Subclavian (C5 and C6)	Subclavius muscle.
72	Suprascapular (C5 and C6)	Supraspinatus and infraspinatus muscles.
73	Thoracodorsal (C6-C8)	Latissimus dorsi muscle.
74	Subscapularis (C5 and C6)	Subscapular and teres major muscles.
75	Axillary (C5 and C6)	Deltoid and teres minor muscles, skin over shoulder.
76	Musculocutaneous (C5-C7)	Biceps coracobrachialis, brachialis muscles.
77	Lateral cutaneous of forearm	Skin of radial side of forearm.

	Tibial (L4-S3)	
111	Posterior tibial	Muscles of back of calf, skin of heel.
112	Med. and lat. plantar	Skin of bottom of foot and toes, intrinsic muscles of foot.
113	Sural	Skin of back of calf and lateral side of foot.
	Common peroneal (L4-S2)	
114	Lat. cutaneous of calf	Skin of lateral side of knee and upper calf.
115	Sural communicating	Skin of back of calf and lateral side of foot.
116	Superficial peroneal	Peroneus longus and brevis muscles of calf, skin of lower lateral side of calf and dorsum of foot.
117	Deep peroneal	Anterior muscles of calf, extensor digitorum brevis, skin of dorsum of foot in region of toes I and II.
	Sympathetic Nervous System	
	Nerve or ganglion	
	Superior cervical	
118	Nerve to internal carotid artery	Vasoconstrictor fibers to circle of Willis and cerebral arteries, dilatator pupillae and ciliary muscle[4], lacrimal gland.
119	Nerve to external carotid artery	Blood vessels and sweat glands of face, submaxillary and sublingual glands[6], parotid gland[7].
120	Carotico-tympanic nerves	Tympanic plexus.
121	Laryngo-pharyngeal nerves	Pharyngeal and laryngeal plexus via superior laryngeal nerve.
122	Rami communicantes (C2-C4)	Cervical plexus, blood vessels and sweat glands of posterior scalp and neck.
123	Superior cardiac	Heart via cardiac plexuses.
	Middle cervical	
124	Middle cardiac	Heart via cardiac plexuses.
125	Rami communicantes	Upper brachial plexus.
	Inferior cervical	
126	Inferior cardiac	Heart via cardiac plexuses.
127	Pulmonary nerves	Bronchi and pulmonary vessels via pulmonary plexuses.
128	Rami communicantes	Brachial plexus.
129	Vertebral ramus	Vasoconstrictor fibers to vertebral artery.
	Thoracic, abdominal and pelvic	
130	Rami communicantes (Ganglia 1-12)	Intercostal nerves.
131	Thoracic cardiac nerves (Ganglia 1-4)	Heart via cardiac plexuses.
132	Pulmonary nerves (Ganglia 1-4)	Bronchi and pulmonary vessels via pulmonary plexuses.
133	Esophageal nerves (Th5-Th6)	Upper esophagus via esophageal plexus, lower esophagus and upper gastric orifice via periaortic plexus.
134	Greater splanchnic (Ganglia 5-9), lesser splanchnic (Ganglia 10 and 11) and least splanchnic (Ganglion 12)	Celiac and aortico-renal ganglia. Via celiac plexus to following plexuses: (a) left gastric (esophagus and stomach), (b) hepatic (liver, gallbladder, stomach, duodenum and pancreas), and (c) splenic (spleen, pancreas, and stomach). Also via following plexuses with branches from periaortic plexus: adrenal (adrenal gland), renal (kidney) and superior mesenteric (small intestine, cecum, appendix, ascending and transverse colon).
135	Splanchnics plus fibers from lumbar ganglia	Aortic plexus to spermatic (or ovarian) plexus (gonads) and inferior mesenteric plexus (descending colon and rectum).
136	Rami communicantes	Lumboasacral plexus, blood vessels and sweat glands of lower extremities.
137	Hypogastric nerves (continuation of aortic plexus)	Inferior hypogastric, hemorrhoidal (rectum), vesical (bladder), prostatic and uterovaginal plexuses.

/1/ Parasympathetic. /2/ Part of VIIth cranial nerve. /3/ Branch of facial nerve but carries fibers to and from nervus intermedius. /4/ Via ciliary ganglion and short ciliary nerves. /5/ Via deep petrosal nerve, vidian nerve and sphenopalatine ganglion. /6/ Via submaxillary ganglion. /7/ Via external carotid artery.

Values in parentheses are ranges and represent estimate "c" of the 95% range (cf Introduction).

	Species	Nerve, Fiber Type	Conduction Velocity m/sec[1]	Fiber Diameter μ	Temperature °C
		Vertebrata			
	Mammalia				
1		Large motor fibers		(1-30)	
2		Ulnar and median	(30-65)		In vivo
3		(to hand)	(49-69)		In vivo
4	Man	Ulnar and median	(66-69)		In vivo
5		(to forearm)	120		In vivo
6		Tibia & peroneus (to foot)	(47-58)		
7		Sciatic	65		18.7
8		Large motor fibers	110	20	
9			80	15	
10			50	10	
11		N. to gastrocnemius		(11-16)	
12		N. to soleus		(9-12)	
13		N. to tibia ant.		(9-15)	
14		Saphenous, α fibers[2]	60		
15		Small motor fibers	40	8	
16			30	6	
17			20	4	
18			10	2	
19	Cat	N. to gastrocnemius		(3-8)	
20		N. to soleus		(3-6)	
21		N. to tibia ant.		(3-6)	
22		Splanchnic, β fibers[2]	(70-81)	(13-15)	35
		Afferent fibers			
23		Flexor hamstrings	(47-111)	(13-22)	37.5
24		Pre-tibial	(27-99)	(13-22)	37.5
25		Gastrocnemius	(30-104)	(13-22)	37.5
		Spinal cord			
26		Pyramidal tract	(1.8-164)	(1-12.5)	37
27		Dorsal columns	(22-66)		
28		Dorsal spinocerebellar	85-160	(16-18)	
29		A fibers (fastest)[2]	100		
30		B fibers[2]	4.5	3	
31		C fibers[2]	0.6	1-5	
32	Dog	Sciatic	(59-102)		38
33		Chorda tympani	36.4	8.2	38
34		Splanchnic	55.0		
35		Saphenous	(72-83)	(14.4-17)	38
36	Rabbit (Oryctolagus cuniculus)	Depressor	5	(2-4)	38
37		Peroneal	69	20.4	37.5
38	Rat (Rattus rattus)	Tibial	37.8	(2.6-12.5)	20
	Reptilia				
39	Blow snake (Pituophis catenifer)	Spinal motor pathways	(11.0-36.9)		14-24
40	Bull snake (Pituophis sp)	Hypoglossal	(7.5-11.2)		22-27
41	Garter snake (Thamnophis sp)	Spinal motor pathways	(3.42-35.1)		10.5-22
42	King snake (Lampropeltis sp)	Hypoglossal	10		
	Amphibia				
43	Frog (Rana sp)	Sciatic, A fibers[2]	2 x d[1], 40 max.	(3-20)	24[1]
44		Muscle nerve	(10-40)	15	22
45			(4-8)	5	22
46		Large motor fibers		(7-11)	
47		Small motor fibers		(4-6)	
48	Frog (R. catesbeiana)	C fibers[2]	(0, 2-0.6)	<1	
49		Large motor fibers	30	15	
50			25	12	
51			20	10	
52	Frog (Rana catesbeiana)	Small motor fibers	15	8	
53	(concluded)		10	5	
54			7	4	
	Pisces				
55	Bullhead (Ameiurus sp)	Spinal pathway[3]	50-60	22-43	10-15
56	Catfish	Optic n. (proximal)	3-8		
57		(peripheral)	15-25		
58	Pike (Esox)	Olfactory n.	16-24		20
59	Ray (Raja equalus)	Dorsal roots	8-36	2-17	
60	Torpedo (Torpedo sp)	Electric organ (aff.)	20-30		18-19
		Invertebrata			
	Arthropoda				
	Crustacea				
61	Crab (Carcinus maenas)	Leg	4.4(3.9-5.5)	30	21
62	Crayfish (Cambarus sp)	Lateral giant fibers	(10-15)	(75-150)	20
63		Median giant fibers	(15-20)	(100-250)	20
64	Lobster (Homarus spp)	Leg nerve fibers	4(2-10)	(35-70)	23
65	Mud shrimp (Callianassa sp)	Giant fibers	(6.0-7.5)	(35-40)	20-22
66	Prawn (Leander sp)	Giant fibers	(18-23)	35	17
	Insecta				
67	Cockroach (Periplaneta sp)	Giant fibers	(9-12)	(10-40)	
	Xiphosura				
68	King crab (Limulus sp)	Ambulacral n.	(1.3-4.6)		
69		Heart plexus	1.5		
	Mollusca				
70	Cuttlefish (Sepia sp)	Giant fibers	(6-13)	200	
71		Stellar n.	(2.2-8.1)	(30-180)	
72	Octopus (Octopus sp)	Mantle	2		
73	Slug (Arrolimax columbianus)	Pedal n.	0.83	1-35	21.8
74			0.50	1-35	7.6
75	Snail (Helix pomatia)	Intestinal n.	(0.05-0.48)	10-15	
76	Squid (Loligo forbesi)	Stellar n.	(4.7-22.3)	(40-210)	
77	Squid (L. pealii)	Giant fibers	18	260	20.8-24.3
78		Giant fibers	23.5(21.5-29)	350	20.8-24.3
79		Giant fibers	30(27.5-32)	450	20.8-24.3
80		Giant fibers	35	520	20.8-24.3
	Annelida				
81	Clamworm (Neanthes virens)	Lateral giant fibers	5(4-6)	(30-37)	24
82		Median giant fiber	4.5	(15-18)	24
83		Medial giant fibers	2.5	(7-9)	24
84	Earthworm (Lumbricus	Lateral giant fibers	11.3(7.5-15)	(40-60)	21-24
85	terrestris)	Median giant fiber	30(15-45)	(50-90)	21-24
86	Leech (Hirudo sp)	Ganglionic cords	(0.02-0.03)		
87	Lugworm (Arenicola sp)	Giant fiber	2	25	24
88	Sabellid (Myxicola sp)	Giant fiber	(6-20)	(100-1000)	
89	Sandworm (Lumbrineris hebes)	Median dorsal fiber	10	130	24
90		Median ventral fiber	4.5	27	24
91	Sea mouse (Aphrodita sp)	Nerve cord	0.5		
	Coelenterata				
92	Aurelia (Aurelia sp)	Nerve net	0.229		
93	Portug. man-of-war (Physalia sp)	Filaments[4]	0.121		26
94	Sea anemone (Calliactis	Column n. net, longit.	0.1		
95	parasitica)	circular	0.15		
96		radial	0.04		
97		Mesentery n. net, longit.	1.2		

/1/ Velocity (v) in m/sec (myelinated fibers) in vertebrates is directly proportional to outside diameter in μ; v = kd, k≈6 in mammals; k≈2 in frogs. Temperature coefficient of velocity is 1.8 for 10°.
/2/ A fibers = myelinated fibers of somatic system, subdivided into α, β, γ and δ; B fibers = myelinated (usually preganglionic) fibers of autonomic nervous system; C = non-myelinated fibers. /3/ Presumed to be Mauthner's fibers. /4/ Presumably nerve net.

289. DELAYS AT SYNAPSES AND PERIPHERAL JUNCTIONS

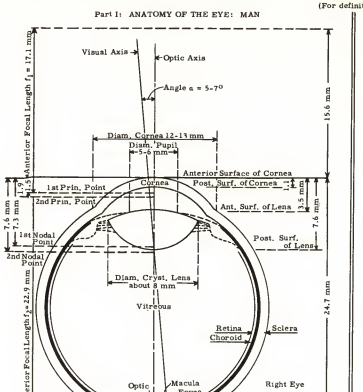
Synaptic delay is the time between first electrical sign of impulse in presynaptic terminals and first electrical sign of response in the postsynaptic unit. The latter is often a synaptic potential and not a spike. Values are not strictly comparable because of varying interpretations with regard to the exact moment an impulse enters presynaptic terminals or with respect to bases for correction for conduction. Because spike may be initiated any time up to or slightly beyond crest of junction potential, values for crest time (foot to summit) of such potentials are listed separately.

	Species	Preparation, Junction, Condition	Corrected Delay msec	Temp °C
		Synapses		
1	Cat (Felis catus)	Neuromuscular junction, soleus and other muscles.	0.55–0.65[1]	37–39
2		Monosynaptic reflex, ventral horn motoneurons, wire electrodes.	0.3–0.45[2]	37
3		Cochlear nucleus in medulla.	0.8[3]	
		Sympathetic ganglion.		
4		Superior cervical, synapse facilitated,	2.0[4]	35
5		Stellate ganglion, in situ.	3.0–4.0[2]	37–39
6	Cockroach (Periplaneta americana)	Last abdominal ganglion, cercal afferents to ascending giant fibers.	0.6–1.5	
	Crayfish (Cambarus sp)	First synapse in proprioceptive pathway		
7		Exposed ventral ganglia.	3.5–4.5[5]	
8	Crayfish (C. clarkii)	Lateral giant fibers, segmental, septal synapse.	<0.1	
9		Lateral giant fibers, commissural synapse.	0.5	
10		Ipsilateral medial giant to 3rd root motor fiber, slightly fatigued.	0.6	
11	Earthworm (Lumbricus terrestris)	Oblique septum between segments1 giant fiber units.	0.1[5]	24
12	Frog (Rana sp)	Neuromuscular junction, semitendinosus.	0.8	22.5
13	Plume worm (Protula intestinum)	Natural synapse between giants, in brain, fresh to fatigued.	0.8–6.5	16
14		"Quasi-artificial" jumping between giant fibers, fresh to fatigued.	0.6–7+	16
15	Rabbit (Oryctolagus cuniculus)	Trochlear motoneurons.	0.5–0.9[6]	37
16	Sea anemone (Metridium senile)	Mesentery nerve net, through-conduction pathway	<2.5[7]	
17	Shrimp, ghost (Callianassa californiensis)	Last abdominal ganglion, giant central fiber to motor fibers in telson	0.25	20–22
18	Slug (Ariolimax columbianus)	Isolated pedal ganglion.	33.0	7.6
19		Isolated pedal ganglion	19.0	21.8
20	Squid (Loligo opalescens)	Synapse in stellate ganglion, 2nd and 3rd order giant fibers.	0.5	24
	Turtle (Pseudemys sp)	Superior cervical ganglion		
21		B-fibers, pre- and post-ganglion.	8.0[7]	
22		C-fibers, pre- and post-ganglion.	25.0[7]	
		Artificial Synapses		
23	Cat (Felis catus)	Cut end of nerve, A-fibers, motor to sensory.	0.1–0.3[8]	
24		Cut end of dorsal columns of spinal cord, dorsal root to dorsal root.	0.1–0.3[9]	
25	Crab (var. spp)	Two isolated nerves or fibers in contact.	7+	
	Cuttlefish (Sepia officianalis)	Two isolated nerves or fibers in contact.		
26		Giant fibers, normal or citrated,	2.5[10]–5.0	
27		Citrated, rhythmic subthreshold activity.	>40.0[10]	
28	Earthworm (lumbricus terrestris)	Single giant fiber, after discharge arising near anodally depressed locus.	5+	
		Mechanoreceptors		
29	Cat (Felis catus)	Pacinian corpuscle, single mesenteric.	0.5–1.5[8]	
30		Baroreceptors in carotid body, single fibers.	<10[5, 10, 11]	
31		Auditory nerve spikes, click stimulus.	0.6–0.8	
32	Crayfish (Cambarus sp)	Tactile hairs on telson.	0.5–1.5	
33	Frog (Rana temporaria)	Touch receptors, dorsal skin.	0.7–14.6[5]	20.6-29.6
34	Guinea pig (Cavia porcellus)	Cochlear microphonic to action potential.	0.15	
		Radiation Receptors		
35	Cat (Felis catus)	Electroretinogram (ERG), a-wave.	4.0	
36		ERG, b-wave.	25–80[4, 10]	
37	Clam (Mya arenaria)	Photoreceptors in siphon, electrogram.	720–16,000	20
38	Crab, horseshoe (Limulus polyphemus)	Spikes in optic nerve, near-maximal and near-threshold stimuli.	77–750	
39		ERG, intracellular electrode in ommatidial receptor.	70	
40		ERG, near-maximal light flash.	10^{12}–55	25–28
41	Fly (Calliphora erythrocephala)	ERG, near-maximal stimuli, compound eye.	$6.0^{10, 12}$	
42	Frog (Rana sp)	ERG, a-wave, isolated eye, maximal stimuli.	28–120	
43	Grasshopper (Melanoplus differentialis)	ERG, near-maximal stimuli.	9.3^{12}–59.6	
44	Pigeon (Columba sp)	ERG, a-wave.	8.0	
45	Rattlesnake (Crotalus viridis)	Infrared receptor in facial pit organ .	15–50[13]	23
46	Sister, rock (Ligia occidentalis)	ERG, compound eye, near-maximal stimuli.	6^{12}–20	22
		Crest Times		
47	Cat (Felis catus)	Neuromuscular junction, circulated soleus strip.	0.8[13]	37–39
48		Spinal cord, ventral horn motoneuron, internal electrode.	0.6–1.0[14]	36–38
49	Crab (var. spp)	Various leg muscles, end-plate potential.	3.0	17
	Frog (Rana temporaria)	Neuromuscular junction.		
50		Isolated skeletal muscle, internal electrode.	1.2[13]	20
51	Frog (Hyla sures)	Isolated fiber; external microelectrode on single end-plate.	0.5	
52	Plume worm (Protula intestinum)	Giant synapse in brain, in situ.	1.0	16
53	Rabbit (Oryctolagus cuniculus)	Sympathetic ganglion, stellate, in situ.	10–20	37–39
54		Sympathetic ganglion, isolated superior cervical.	25–35[13]	35

/1/ Decerebrate or nembutal. /2/ Nembutal. /3/ Avertin. /4/ Decerebrate. /5/ Uncorrected for conduction time. /6/ Decorticate. /7/ Measured from 1st reversal of sign of prespike; conduction-time correction not stated. /8/ Decerebrate or chloralose. /9/ Dial. /10/ Measured from illustrations. /11/ Chloralose-urethane. /12/ Probably minimum, i.e. light intensity probably nearly maximal. /13/ Curarized. /14/ Pentobarbitone.

(For definition of terms, see Glossary, Part XVI.)

Part I: ANATOMY OF THE EYE: MAN



/1/ Blind spot.

Part II: OPTICAL CONSTANTS OF EYES: MAMMALS

Values in brackets refer to state at maximal accomodation.

	Constant	Eye Area or Measurement	Man	Cat	Dog	Horse	Ox	Sheep	Swine
1	Refractive index	Cornea	1.37	1.37	1.37	1.37	1.37	1.37	1.38
2		Aqueous humor	1.33	1.33	1.33	1.33	1.33	1.33	1.33
3		Lens capsule	1.38[1]	1.37	1.37	1.38	1.38	1.36	1.36
4		Outer cortex, lens		1.38		1.39	1.38	1.37	1.38
5		Ant. cortex, lens			1.38	1.39	1.38	1.38	
6		Post. cortex, lens			1.38	1.39	1.38	1.38	
7		Center, lens	1.41	1.46	1.44	1.45	1.46	1.45	1.44
8		Calc. total index	1.41	1.52		1.50	1.55	1.53	1.48
9		Vitreous body	1.33	1.33	1.33	1.33	1.33	1.33	1.33
10	Radius of curvature, mm	Cornea	7.7	9.5	8.7	18.7	16.8	12.7	11.0
11		Ant. surface, lens	9.2-12.2	6.7	6.5	14.0	11.3	8.9	7.2
12		Post. surface, lens	5.4-7.1	6.4	5.5	10.1	9.7	7.9	6.3
13	Distance from cornea, mm	Post. surface, cornea	1.2	0.8-1	0.5	1-1.5	1.5-2	0.8-1.2	1-1.2
14		Ant. surface, lens	3.5	4.5	4.8	5.5	4.4	3.0	2.8
15		Post. surface, lens	7.6	12	12	18	16	13	12
16		Retina	24.8	21	21	42	36	28	25
17	Focal distance, mm	Ant. focal length	17.1 [14.2]						
18		Post. focal length	22.8 [18.9]						
19	Position of cardinal points measured from corneal surface, mm	1. Focus	-15.7 [-12.4]						
20		2. Focus	24.4 [21.0]						
21		1. Principal point	1.5 [1.8]						
22		2. Principal point	1.9 [2.1]						
23		1. Nodal point	7.3 [6.5]						
24		2. Nodal point	7.6 [6.8]						
25	Diameter, mm	Optic disk	2-5						
26		Macula	1-3						
27		Fovea	1.5						
28	Depth, mm	Anterior chamber	2.7-4.2						

/1/ Cortex of lens and its capsule.

Part III: VOLUME OF EYEBALL AND ITS PARTS: MAMMALS

Values are milliliters; those in parentheses are ranges.

	Animal	Eyeball	Lens	Anterior Chamber	Posterior Chamber	Vitreous
1	Man	5.4	0.2	0.3	0.2	3.9
2	Cat	3.9	0.5	0.6	0.3	2.8
3	Dog	4.4(1-5)	0.5	0.4	0.2	3.2
4	Horse	45(40-47)	2.8	2.4	1.6	28.8
5	Ox	32(28-44)	2.2	1.7	1.5	20.9
6	Rabbit	3.0	0.2	0.3	0.1	2.0
7	Sheep	12.2(8-14)	0.9	0.8	0.5	7.0
8	Swine	7.22(3-9)	0.8	0.3	0.3	5.7

Part IV: DIMENSIONS OF EYEBALL: VERTEBRATES

Values are millimeters.

	Animal	Horizontal	Vertical	Sagittal
1	Man	24.0	23.5	24.0
2	Elephant, Indian	41.0	40.0	35.1
3	Fox	16.0	16.0	15.4
4	Gorilla	22.5	22.5	22.5
5	Horse	50.5	50.5	45.5
6	Lion	35.0		37.5
7	Mole	1	1	1
8	Swine	26.9	26.0	24.8
9	Whale, great blue	145	129	107
10	Goose		12	10
11	Alligator	20.0	20.0	
12	Iguana	16.6	13.7	14.6
13	Frog	5.8	5.6	5.3
14	Bowfin	12.5	12	10
15	Herring	11.5	11.5	7.5
16	Lamprey	4.9	4.5	4.0

Part V: RETINA: MAN

Section 1: General Characteristics

	Designation	Cones	Rods
1	20 min angle = 100 μ		
2	Thickness, extrafovea, 300 μ		
3	Thickness, fovea, 125-135 μ		
4	Approx. diam. of fovea, 300 μ		
5	No. nerve fibers in optic nerve, 800,000-1,000,000		
6	No. receptors for each eye	7 million	125 million
7	Total receptors in fovea	12,000	0
8	Diam. of receptor, μ	1.0-5.0	1.0-2.5
9	Photochemical substance	(Rodopsin)[1]	Rhodopsin
10	Wave length for max. sensitivity, μ	0.56	0.51
11	Approx. range of response, μ	0.4-0.75	0.40-0.65
12	Sensation	Chromatic	Mono-chromatic
13	Absolute threshold, millilamberts	0.01	0.000001
14	Approx. time for dark adaptation, min	2	30

/1/ Found only in retina of chicken.

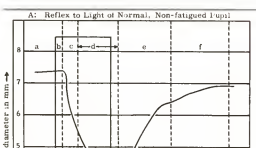
Section 2: Rod and Cone Population and Cone Acuity[1]

Values in parentheses are ranges.

	Angular Eccentricity[2] degrees	Population Rods/sq mm thousands	Population Cones/sq mm	Visual Angle Subtended at Eye minutes
1	0	0	136	0.7(0.5-1.0)
2	1/4	0	84.4	0.8(0.6-1.1)
3	1/2	7.22	57.5	1.0(0.7-1.3)
4	3/4	12.4	49.1	1.1(0.8-1.5)
5	1	34.2	41.3	1.2(0.8-1.5)
6	1 1/2	53.0	29.3	1.4(0.8-2.0)
7	2	56.9	25.3	1.7(1.0-2.3)
8	6	105	12.1	4.5(1.5-6.7)
9	12	125	7.64	6.1(2.5-10)
10	20	158	7.08	10(5.0-17)
11	40	132	5.95	27.5(14-48)
12	50	108	5.79	42.5(21-72)
13	70	80.4	5.47	$100(47 - X^3)$
14	90	57.7	6.84	$X^3/(26 - X^3)$

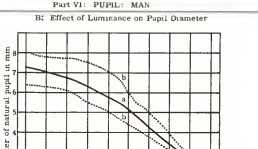
/1/ At or near horizontal meridian. /2/ From fovea. /3/ Unmeasurably poor acuity.

A: Reflex to Light of Normal, Non-fatigued Pupil



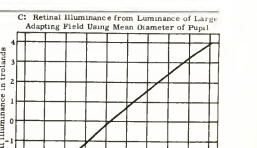
a = dark adapted pupillary diameter; b = latency period for contraction; c = first (fast) phase of contraction; d = second (slower) phase of contraction; e = first (faster) phase of redilation; f = second(slower) phase of redilation.

B: Effect of Luminance on Pupil Diameter



a=average of 8 studies; b=extreme of means of 6 studies.

C: Retinal Illuminance from Luminance of Large Adapting Field Using Mean Diameter of Pupil



D: Accommodation[1]

Values in parentheses are ranges.

	Age yr	Amplitude Diopter
1	10	14(11.5-16.5)
2	14	12.4(9.9-14.9)
3	18	10.8(8.5-13.3)
4	22	9.4(7.4-11.7)
5	26	8.2(6.3-10.2)
6	30	7.0(5.5-8.5)
7	34	5.8(4.3-7.3)
8	38	4.8(3.7-6.1)
9	42	4.1(3.1-5.1)
10	46	3.3(2.3-4.3)
11	50	2.5(1.7-3.0)
12	54	1.8(1.3-2.3)
13	58	1.2(0.7-1.7)
14	62	0.8(0.45-1.1)
15	66	0.4(0.15-0.8)
16	68	0.2(<0.1-0.5)
		Near Point, cm
17	10	7.2(6.1-8.7)
18	14	8.1(6.7-10.1)
19	18	9.3(7.5-11.8)
20	22	10.6(8.5-13.5)
21	26	12.2(9.8-15.7)
22	30	14.3(11.8-18.2)
23	34	17.2(13.7-23.2)
24	38	20.8(16.4-27.0)
25	42	24.4(19.6-32.3)
26	46	30.3(23.3-43.4)
27	50	40.0(33.3-58.8)
28	54	55.6(43.5-76.9)
29	58	83.3(58.8->100)
30	62	>100(91.0->100)
31	66	>100
32	68	>100

[1] Subjective measurements.

A: Relative Effectiveness of Different Wave Lengths
100 = maximal sensitivity or effectiveness

	Wave Length mμ	Color Spectrum	Rods	Cones	Scotopic	Photopic
1	400					
2	450	Violet	40	5	37	6
3	500	Blue	100	33	97	36
4	511				100	60
5	550	Green	55	100	60	99
6	554				41	100
7	600	Yellow	7	65	10	64
8	650	Red	Slight	13	1	14
9	700		0	Slight	0	2

C: Spectral Sensitivities of Rods and Cones

Values are log sensitivity (log1/threshold) at various wave lengths in a 1° circular field exposed for flashes of 1/25 sec.

	Wave Length mμ	Normal Eyes Foveal[1]	8° above Fovea Rods[1]	8° above Fovea Cones[1]	Aphakic[1] Eyes 8° above Fovea Rods[2]	Cones[2]
1	365	5.401	2.042	6.95	2.62	2.42
2	405	3.806	0.427	3.64	1.05	2.88
3	436	2.643	1.675	2.67	1.48	1.22
4	492	1.288	2.295	1.25	0.00	1.80
5	546	1.980	2.095	1.65	1.78	0.01
6	578	1.966	1.375	1.59	1.12	1.90
7	621	1.626	0.038	1.27	3.87	1.63
8	691	3.840	3.635	3.43	5.39	3.87
9	713	3.048	4.787	4.59	6.52	5.11
10	750	4.072	5.890	5.68	7.68	4.18

[1] Values are relative to foveal maximum sensitivity. [2] Values are relative to maximal sensitivity of aphakic dyes.

B: Relative Luminosities

	Wave Length mμ	Photopic (CIE[1] 1924)	Mesopic (Weaver 1949) Logarithm of Adapting Luminance, Ft-L -0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0	Scotopic (CIE[1] 1951 for Young Eyes)
1	380	0.00004		0.0001	0.0002	0.0008	0.0015	0.0025	0.0034	0.0045	0.00059
2	400	0.0004	0.0004	0.0008	0.0022	0.0059	0.0098	0.0147	0.0185	0.0228	0.00929
3	420	0.004	0.0044	0.0069	0.0152	0.0280	0.0427	0.0580	0.0690	0.0820	0.09661
4	440	0.023	0.0240	0.0300	0.0496	0.0850	0.123	0.160	0.183	0.216	0.3281
5	460	0.060	0.0627	0.0775	0.127	0.202	0.277	0.339	0.376	0.423	0.5672
6	480	0.139	0.146	0.180	0.288	0.432	0.540	0.604	0.649	0.685	0.7931
7	490	0.208	0.220	0.274	0.426	0.592	0.687	0.734	0.782	0.814	0.9029
8	500	0.323	0.340	0.416	0.603	0.744	0.826	0.864	0.902	0.930	0.9818
9	510	0.503	0.524	0.617	0.766	0.876	0.935	0.962	0.977	0.992	0.9966
10	520	0.710	0.726	0.792	0.894	0.965	0.992	0.999	0.988	0.974	0.9352
11	530	0.862	0.872	0.910	0.972	1.000	0.982	0.951	0.924	0.883	0.8110
12	540	0.954	0.959	0.979	1.000	0.969	0.909	0.842	0.796	0.744	0.6497
13	550	0.995	0.997	1.000	0.971	0.886	0.785	0.698	0.642	0.583	0.4808
14	560	0.995	0.992	0.973	0.898	0.760	0.640	0.543	0.478	0.419	0.3288
15	570	0.952	0.944	0.907	0.782	0.617	0.485	0.384	0.330	0.281	0.2076
16	580	0.870	0.860	0.802	0.648	0.468	0.340	0.259	0.218	0.182	0.1212
17	590	0.757	0.742	0.673	0.509	0.333	0.227	0.166	0.137	0.112	0.06548
18	600	0.631	0.616	0.544	0.374	0.224	0.145	0.101	0.0830	0.0670	0.03315
19	610	0.503	0.490	0.416	0.257	0.142	0.0870	0.0600	0.0488	0.0388	0.01593
20	620	0.381	0.366	0.296	0.168	0.0845	0.0504	0.0344	0.0280	0.0225	0.00737
21	630	0.265	0.250	0.197	0.102	0.0480	0.0282	0.0194	0.0156	0.0127	0.00334
22	640	0.175	0.162	0.122	0.0590	0.0270	0.0146	0.0107	0.0085	0.0070	0.00150
23	650	0.107	0.0990	0.0710	0.0327	0.0147	0.0084	0.0058	0.0046	0.0037	0.00068
24	660	0.061	0.0560	0.0390	0.0174	0.0078	0.0045	0.0031	0.0025	0.0020	0.00031
25	680	0.017	0.0153	0.0103	0.0046	0.0022	0.0014	0.0009	0.0007	0.0006	0.000072
26	700	0.0041	0.0038	0.0026	0.0012	0.0006	0.0003	0.0002	0.0002	0.0001	0.000018
27	720	0.0010	0.0010	0.0007	0.0003	0.0001					0.000005
28	740	0.0003	0.0002	0.0002							0.000001
29	750	0.0001	0.0001								0.0000008

[1] Standard values adopted by the Commission Internationale de l'Eclairage.

A: Tristimulus Values of the Spectrum

Values represent the magnitudes of each of the 3 standard primaries necessary to match the given spectral light. These primaries are imaginary; for convenience, $\bar{y}$ corresponds to the overall luminosity function of the standard observer, but, as an approximation, $\bar{x}$ may be regarded as red, $\bar{y}$ as green, and $\bar{z}$ as blue.

	Wave Length mμ	$\bar{x}$	$\bar{y}$	$\bar{z}$		Wave Length mμ	$\bar{x}$	$\bar{y}$	$\bar{z}$
1	380	0.0014	0.0000	0.0065	31	585	0.7986	0.8163	0.0014
2	400	0.0143	0.0004	0.0679	32	590	1.0263	0.7570	0.0011
3	410	0.0435	0.0012	0.2074	33	595	1.0567	0.6949	0.0010
4	420	0.1344	0.0040	0.6456	34	600	1.0622	0.6310	0.0008
5	430	0.2839	0.0116	1.3856	35	605	1.0456	0.5668	0.0006
6	440	0.3483	0.0230	1.7471	36	610	1.0026	0.5030	0.0003
7	450	0.3362	0.0380	1.7721	37	615	0.9384	0.4412	0.0002
8	460	0.2908	0.0600	1.6692	38	620	0.8544	0.3810	0.0002
9	470	0.1954	0.0910	1.2876	39	625	0.7514	0.3210	0.0001
10	480	0.0956	0.1390	0.8130	40	630	0.6424	0.2650	
11	485	0.0580	0.1693	0.6162	41	635	0.5419	0.2170	
12	490	0.0320	0.2080	0.4652	42	640	0.4479	0.1750	
13	495	0.0147	0.2586	0.3533	43	645	0.3608	0.1382	
14	500	0.0049	0.3230	0.2720	44	650	0.2835	0.1070	
15	505	0.0024	0.4073	0.2123	45	655	0.2187	0.0816	
16	510	0.0093	0.5030	0.1582	46	660	0.1649	0.0610	
17	515	0.0291	0.6082	0.1117	47	665	0.1212	0.0446	
18	520	0.0633	0.7100	0.0782	48	670	0.0874	0.0320	
19	525	0.1096	0.7932	0.0573	49	675	0.0636	0.0232	
20	530	0.1655	0.8620	0.0422	50	680	0.0468	0.0170	0.0000
21	535	0.2257	0.9149	0.0298	51	690	0.0227	0.0082	
22	540	0.2904	0.9540	0.0203	52	700	0.0114	0.0041	
23	545	0.3597	0.9803	0.0134	53	710	0.0058	0.0021	
24	550	0.4334	0.9950	0.0087	54	720	0.0029	0.0010	
25	555	0.5121	1.0002	0.0057	55	730	0.0014	0.0005	
26	560	0.5945	0.9950	0.0039	56	740	0.0007	0.0003	
27	565	0.6784	0.9786	0.0027	57	750	0.0003	0.0001	
28	570	0.7621	0.9520	0.0021	58	760	0.0002	0.0001	
29	575	0.8425	0.9154	0.0018	59	770	0.0001	0.0000	
30	580	0.9163	0.8700	0.0017	60	775	0.0000	0.0000	

B: Classification and Characteristics of Abnormal Color Vision Systems

	Type[1]	Designation	Common Name	Discrimination Possible	No. of Ligits to Match Spectrum	Neutral Points	Appearance of Spectrum	λ_n[2] of Max. Luminosity, mμ	Saturation Characteristics
1	Monochromatic	Achroma-topsia	Total color blindness	Light-dark	1 (can match all stimuli by adjusting to equal brightness)	All	Achromatic	Red monochromats 510[3] (cone monochromats 560)	0 (Throughout spectrum)
2	Dichromatic	Protanopia	Red-green blind	Light-dark, yellow-blue	2 (yellow and blue)	493	Blue (short λ_n)	540	0 at neutral point; 1 toward long and short ends of spectrum
3		Deuteranopia				497	Yellow (long λ_n)	560[4]	
4		Tritanopia	Yellow-blue blind	Light-dark, red-green	2 (red and green)	572	Green (short λ_n) Red (long λ_n)	560	
5	Anomalous trichromatic	Protanomaly	Red-green weak	Light-dark; yellow-blue; red-green weak	3 (in different proportions from those required by normals)	None	Intermediate between normal and respective dichromatic types	540[5]	Intermediate between normal and respective dichromatic types
6		Deuteranomaly						560[4]	
7		Tritanomaly	Yellow-blue weak	Light-dark; red-green; yellow-blue weak					

/1/ According to number of components (lights required to match spectrum). /2/ Wave length. /3/ As in dark-adapted normals. /4/ Similar to normals. /5/ Deficient at long wave lengths.

C: Incidence of Color Defectiveness: European-American Males
Values are percentages of populations.

	Degree of Color Defectiveness				Ratio Male to Female
	Total	Anomalous Trichromats	Dichromats	Monochromats	
	8.2	5.8	2.4	0.004[1]	
Type of Color Defectiveness	Protans 2.2	Protanomalous 1.0	Protanopes 1.2		16:1
	Deutans 6.0	Deuteranomalous 4.8	Deuteranopes 1.2		
	Tritans 0.00020	Tritanomalous 0.00015	Tritanopes 0.00005		3:2

/1/ (Estimated) rod 0.004; cone 0.00001.

D: Incidence of Defective Color Vision: Various Populations
Values are per cent failing Ishihara[1] test.

Population	Male	Female
U. S. A.	6.8-9.7	0.2-1.3
European, Caucasian (Brit., Scot., Norway, Ger.)	7.5-8.0	0.4-0.6
Chinese	4.0-6.9	0.4-1.7
Japanese	2.4-6.9	0.35
American Negro	3.9	0.2
American Indian	1.1-2.0	0-0.7
Mexican	2.3	0.5

/1/ Criterion of failure: 2 or more plates miscalled on 5th edition Ishihara, or equivalent.

E: Wave Length Discrimination[1]
Values are given in mμ for λ-(wave length) and $\Delta\lambda$- (just noticeable difference in wave length, averaged from $\Delta\lambda$'s at graduated stimulus intensities).

	λ	$\Delta\lambda$		λ	$\Delta\lambda$		λ	$\Delta\lambda$
1	430	6.5	15	515	2.4	29	585	1.4
2	435	5.0	16	520	2.7	30	590	1.3
3	440	3.8	17	525	2.9	31	595	1.3
4	445	3.3	18	530	3.1	32	600	1.4
5	450	3.5	19	535	3.2	33	605	1.5
6	460	3.3	20	540	3.1	34	610	1.6
7	470	2.5	21	545	2.9	35	615	1.7
8	475	2.2	22	550	2.7	36	620	1.9
9	480	1.8	23	555	2.4	37	625	2.2
10	490	1.6	24	560	2.2	38	630	2.5
11	495	1.6	25	565	1.9	39	635	3.0
12	500	1.7	26	570	1.7	40	640	3.6
13	505	1.8	27	575	1.6	41	645	4.5
14	510	2.0	28	580	1.5	42	650	5.9

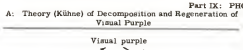
/1/ Monocular observations by 5 subjects (with normal color vision) of matching bipartite field at 2°. Illumination averaged 70 photons with a dark surround; an artificial pupil had 1.016mm diameter.

F: Color Vision: Animals.

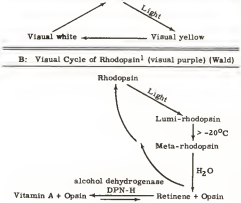
	Animal	Predominant Retinal Elemeots	Wave Length Discrimination	Spectral Range	Probable No. Primary Colors
1	Man, chimpanzee, rhesus monkey	Rods, cones	1-2 mμ at optimal λ	400-700 mμ, approximately	3
2	Cebus monkey	Rods, cones	Good except at yellow (589 mμ) and longer	↓ toward long λ-'s	2
3	Cat, cow, dog, mouse, rabbit	Rods	Weak or absent	↓ toward long λ-'s	Unknown
4	Chicken, pigeon	Cones	Equivalent to man	Slight shift toward long λ-'s	3
5	Turtle (Chemmys caspica)	Cones	Very good	Equivalent to man	3
6	Fish (Phoxinus laevis)	Rods, cones	Very good	Possible shift toward short λ-'s	3
7	Callithrox	Compound eye	Fair	Shift toward long λ-'s	Unknown
8	Dromefly (Eristalis tenax)	Compound eye	Present	Unknown	Unknown
9	Honey bee, bumble bee, hawkmoth, Vanessid butterfly	Compound eye	Fair	Shift toward short λ-'s	Unknown
10	Popilionid and Pieridid butterflies	Compound eye	Fair	Range equivalent to man	Unknown

Part IX: PHOTOCHEMISTRY OF VISION

A: Theory (Kühne) of Decomposition and Regeneration of Visual Purple

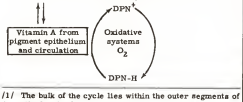


B: Visual Cycle of Rhodopsin[1] (visual purple) (Wald)



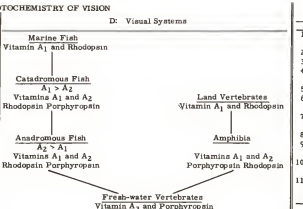
/1/ The bulk of the cycle lies within the outer segments of the retinal rods, but it is supplemented with vitamin A, respiratory factors and oxygen from the pigment epithelium and the blood circulation.

C: Participation of cis-trans Isomers of Vitamin A and Retinene in the Rhodopsin System[1] (Wald)



/1/ Bleaching of rhodopsin yields all-trans retinene. This must be isomerized to the mono-cis, neo-b configuration before it can regenerate rhodopsin. Alternatively, having been reduced to all-trans vitamin A, the latter must be isomerized to neo-b-vitamin A, before it can take part again in rhodopsin synthesis. Rod vision depends therefore upon the continuous stereoisomerization of all-trans retinene or vitamin A, to provide new supplies of the neo-b-isomer.

D: Visual Systems



E: Vitamin A Type and Maximum Spectral Sensitivity io Retinas[1]

	Organism	Absorptive Max. of Vis. Pigment mμ	Proportion of Vit. A1 to Vit. A2
1	Man	497	A1 present
2	Cattle	498	100:0
3	Goat	about 500	100:0
4	Guinea pig	about 500	100:0
5	Rat	498	100:0
6	Sheep	498	100:0
7	Chicken	about 500	
8	Owl (Syrnium aluco)	500	
9	Frog (Rana catesbeiana)	502	A1 present
10	Frog, tadpoles (R. catesbeiana)	520	A2 present
11	Carp (Cyprinus carpio)	522	0:100
12	Chinook (Oncorhynchus tshawytscha)	510-515	29:71
13	Dogfish, smooth (Galeorhinus laevis)	500	100:0
14	Dogfish, spiny (Squalus acanthias)	500	100:0
15	Eel (Anguilla rostrata)	500	62:38
16	Haddock (Melanogrammus aeglifinus)		100:0
17	Lamprey, sea(Petromyzon marinus)		11:89
18	Perch, white (Morone americana)	525	0:100
19	Pickerel (Esox reticulatus)	522	0:100
20	Tautog (Tautoga onitis)		18:82
21	Tench (Tinca vulgaris)	523	
22	Trout, rainbow (Salmo irideus)	510-515	38:62
23	Whiting (Merlucius bilinearis)		100:0
24	Squid (Loligo pealei)	500	

/1/ In scotopic vision. /2/ Not tested for homogeneity.

Part X: FLICKER-FUSION

A: Variables Affecting Critical Flicker Frequency

	Stimulus Variable	Effect on Critical Flicker-Fusion[1]
1	Luminance	Proportional to log intensity of luminance source in midrange of values.
2	Stimulus area	Proportional to log area of source.
3	Light-dark cycle	Max. CFF with light-darkness ratios 1.0-0.5.
4	Surrounds of stimulating field	CFF highest when brightnssses of test fields and surrounds are equal.
5	Method of stimulation	Monocular vs. binocular: binocular ↑.
6	Spectral composition of source	Max. CFF at 570 mμ, falling allgbtly in approx. symmetrical way on either side of max.
7	Retinal area	For stim. areas over 1°, max. CFF usually found 200-400 eccentric to visual axis.
8	2 or 2+ sources in field	Usually interact: CFF ↑.
9	Stimulated phase relation: both eyes	Max. CFF when in phase. Reduced 2-4 cps when 180° out of phase.
10	Intermittence rate	Enhancement of apparent brightness at 8-10 cps (Bartley effect), and at 14-18 cps (Brucke effect).
11	Intersensory effects	When auditory clicks, cutaneous taps, or olfactory puffs are synchronized with visual intermittence, CFF ↑.
	Subject Variable	**Effect oo Critical Flicker-Fusion[1]**
12	Chronological age	CFF inversely proportional to age between 30-95 years.
13	Interindividual differences	Under same conditions, range between individuals about 12 cps.
14	Intraindividual differences	Among 9 out of 10 individuals (unchanged conditions), range of daily CFF determinations should not be over 1.5 cps.
15	Practice	May go up, down or remain unchanged.
16	Duration of observation	CFF increases during 0.1-1.0 sec of observation; constant with observations of 1-10 sec.
17	Accsleration (+)	↑ 2 cps with 2.8-4.8G in centrifuge.
18	Anoxia	↓ at simulated altitude of 10,000-18,000 ft.
19	Brain injury[2]	CFF ↑.
20	Carbon dioxide; carbon monoxide	CFF drops rapidly with inhalation of CO_2 or CO; permanently ↓ after CO poisoning.
21	Refraction	CFF unchanged when glasses are worn.
22	Light vs dark adaptation	CFF ↑ during 15 min light adaptation; ↓ during 60 min dark adaptation.
23	Anxiety	CFF ↓ when compared to normal state.
24	Color blindness[3]	CFF ↓.

/1/ cpsecycles per second; max.=maximum; stim.=stimulated; ↑ =increased; ↓ =decreased. /2/ Or pathology. /3/ Complete.

B: Maximum Critical Flicker Frequencies

	Organism	Max. CFF cps		Organism	Max. CFF cps
1	Man[4]	Rods 15; cones 61-90	32	Turtle[2]	52
			33	Frog[4]	Cones 40
2	Cat[1]	Cones 50	34	Newt[4]	Cones 44
3	Dog	25 (erge)	35	Sunfish[1]	Rods 10, cones 50
4	Rabbit[2]	30			
5	Buzzard[3]	40 (ergs)	36	Teleost[1, 5]	Rods 8; cones 52
6	Chicken[1]	35 (erge)			
7	Finch, zebra[3]	57	37	Crayfish[6]	50
			38	Isopod[6]	52
8	Gecko[2]	27	39	Bee; wasp[6]	300 (erge)
9	Owl[2]	21	40	Cricket[6]	45 (ergs)
10	Pigeon[1]	40 (ergs)	41	Dragonfly[6, 7]	61
11	Lizard[3]	56	42	Fly[6, 8]	250 (ergs)

/1/ Duplex retina. /2/ Rod retina. /3/ Cone retina. /4/ Triplex retina. /5/ Enneacanthus. /6/ Compound eye. /7/ Larva. /8/ Calliphora.

Part XI: WAVE LENGTH OF MAXIMAL SENSITIVITY[1]; ANIMALS AND PLANTS

	Organism	Wave Length $m\mu$
1	Man	560
2	Cat	560
3	Guinea pig	500
4	Rat	500
5	Chicken	560-580
6	Pigeon	580
7	Snake	560
8	Tortoise	620
9	Frog	560
10	Fish, fresh-water	540-610
11	Salt-water	500
12	Crab	480-500
13	Squid	480-500
14	Bee	360[2]
15	Drosophila	360
16	Blowfly larvae	503
17	Tenebrio larvae	535
18	Mya	500
19	Balanus larvae	560-578
20	Arenicola	483
21	Volvox	494
22	Hydra	430-490
23	Eudendrium	460-480
24	Pandorina	524
25	Phacus	483
26	Ameba	430-490
27	Euglena	483
28	Green plants	465
29	Seedlings	blue
30	Avena	440
31	Phycomyces	449

[1] Photopic conditions. [2] Also green.

Part XII: DARK ADAPTATION: MAN

A: Following Light Adaptaton to Various Brightnesses[1]

Values in boxes indicate color was apparent at threshold.

	400,000 Photons		38,900 Photons		19,500 Photons		3800 Photons		263 Photons	
	Time min	Log B_1 μ photons	Time min	Log B_1 μ photons	Time min	Log B_1 μ photons	Time min	Log B_1 μ photons	Time min	Log B_1 μ photons
1	0.19	8.26	0.10	7.16	0.17	6.96	0.18	6.22	0.14	4.78
2	0.52	7.58	0.57	6.53	0.42	6.41	0.42	5.60	0.36	4.38
3	1.1	7.07	1.0	6.11	0.97	6.11	0.67	5.25	0.50	4.12
4	1.5	6.80	2.5	5.90	1.7	5.94	1.3	4.92	0.90	3.88
5	2.2	6.37	3.3	5.81	2.7	5.75	2.1	4.72	1.4	3.71
6	2.7	6.19	4.1	5.76	4.1	5.59	2.9	4.54	2.9	3.57
7	3.4	6.00	5.3	5.75	5.1	5.42	3.8	4.41	4.1	3.45
8	4.4	5.92	6.1	5.67	6.3	5.17	4.9	4.15	5.3	3.33
9	6.4	5.80	7.1	5.61	7.6	4.81	5.9	3.96	6.2	3.24
10	7.7	5.73	7.8	5.45	9.2	4.38	7.7	3.60	7.2	3.07
11	9.5	5.68	8.9	5.26	10.7	3.98	9.4	3.40	8.9	3.02
12	10.7	5.66	9.9	4.99	11.9	3.70	10.6	3.16	10.5	2.91
13	12.6	5.34	10.8	4.77	13.0	3.50	13.5	2.89	11.5	2.82
14	14.3	4.78	12.5	4.28	14.4	3.28	15.0	2.80	13.1	2.80
15	16.0	4.28	14.3	3.81	16.1	3.07	16.4	2.77	15.1	2.72
16	16.7	4.11	15.4	3.52	17.8	2.92	18.2	2.62	17.3	2.61
17	18.0	3.79	16.8	3.29	18.8	2.83	21.9	2.56	19.7	2.58
18	19.6	3.55	18.6	3.13	20.0	2.79	23.7	2.49	23.5	2.51
19	21.5	3.27	20.5	2.99	21.1	2.78	25.4	2.46	25.8	2.55
20	23.0	3.20	22.5	2.92	24.5	2.64	28.8	2.47	27.5	2.51
21	24.2	3.13	23.9	2.88	26.1	2.57			29.6	2.53
22	25.9	3.08	26.0	2.79	27.7	2.57				
23	28.5	2.97	29.3	2.69	29.8	2.58				
24	30.8	2.88	32.0	2.55						
25	33.4	2.84								
26	36.0	2.78								
27	38.6	2.72								

[1] Values, from one observer, are least amounts necessary to produce response. Adapting field: 30° in diameter, white light, fixated 30° nasally on the retina, exposed for 2 minutes. Test field: 5° diameter containing a centered opaque cross 30' wide, violet light, fixated 30° nasally on the retina, exposed for 0.2 second.
[2] Microphotons.

B: Time-Luminance Relation

	Time in Dark min	Log Brightness[1] millilamberts	Adapting Element
1	1/2	-1.5	
2	1	-2.0	
3	2	-2.3	
4	3	-2.5	Cones
5	4	-2.6	
6	5	-2.7	
7	6	-2.73	
8	7	-2.75	← 2
9	8	-3.3	
10	9	-3.8	
11	10	-4.2	Rods
12	15	-5.1	
13	20	-5.3	
14	25	-5.5	
15	30	-5.6	

[1] Values are least amount necessary to produce positive responses. [2] Adaptation curve breaks caused by change from cone to rod vision.

C: Relative Sensitivity of Dark-adapted Eye

	Wave Length $m\mu$	Relative Sensitivity[1] Periphery[2]	Fovea
1	400	-20	+10
2	450	-10	+24
3	500	-3	+26
4	525	0	
5	550	0	+23
6	600	-4	+6
7	650	-10	-10
8	700	-27	-27
9	750	-40	-40

[1] In decibels. [2] 8° above fixation.

Part XIII: VISUAL ACUITY

A: Visual Phenomena as Functions of Luminance: Man

	Log B^1 mL	Pupil Diameter mm	Visual Acuity[1]	Intensity Discrimination, $\Delta B/B$
1	-6.0	7.17		
2	-5.0	7.02		
3	-4.0	6.78	0.08	0.521
4	-3.5		0.11	0.350
5	-3.0	6.37	0.13	0.225
6	-2.5		0.19	0.137
7	-2.0	5.80	0.29	0.080
8	-1.5		0.52	0.048
9	-1.0	5.10	0.80	0.035
10	-0.5	4.74	1.14	0.027
11	0	4.39	1.48	0.021
12	0.5	4.05	1.74	0.017
13	1.0	3.64	2.0	0.015
14	1.5	3.19	2.15	0.012
15	2.0	2.77	2.22	0.015
16	2.5	2.43	2.25	0.017
17	3.0	2.09	2.26	0.024
18	3.5			0.037

[1] White light. [2] An acuity of 1.00 represents a visual angle of a 1' arc.

B: Visual Acuity and Illumination: Man

Test object: Landolt's ring.

	Red [λ= 670 mμ]		Blue [λ= 490 mμ]		White	
	Log I photons	Log V.A.[1]	Log I photons	Log V.A.[1]	Log I photons	Log V.A.[1]
1	-2.88	-1.43	-3.68	-1.47	-3.44	-1.47
2	-2.55	-1.19	-4.09	-1.07	-2.87	-1.16
3	-2.25	-0.95	-3.79	-0.95	-2.42	-0.98
4	-1.85	-0.66	-3.57	-0.78	-2.13	-0.90
5	-1.53	-0.44	-2.32	[-0.65]	-1.85	[-0.84]
6	-1.23	-0.27	-2.02	[-0.56]	-1.85	-1.00
7	-0.81	-0.10	-1.72	[-0.48]	-1.45	[-0.65]
8	0.49	0.02	-1.72	-0.72	-1.45	-0.73
9	-0.19	0.12	-1.28	[-0.38]	-1.16	[-0.45]
10	0.14	0.21	-1.28	-0.45	-1.16	-0.55
11	0.46	0.26	-0.97	[-0.28]	-0.88	[-0.26]
12	1.08	0.30	-0.67	-0.14	-0.88	-0.33
13	1.71	0.33	-0.25	0.02	-0.19	-0.04
14	2.43	0.36	0.36	0.21	0.09	0.06
15	3.15	0.37	1.19	0.30	0.77	0.21
16	3.77	0.38	1.83	0.35	1.50	0.29
17			2.44	0.37	2.47	0.37
18			3.18	0.39	3.44	0.40

[1] Underlined values are rod determinations in a subjectively colorless field; those in brackets, with parafoveal rod and cone vision in a colored field; balance of values, with foveal cone vision in a colored field.

C: Resolving Power of Eyes

	Organism	Test Object	Background Illumination	Minimum Resolvable Angle
1	Man	Dark square	Bright sky	14, 2 sec
2		Dark line	0.006 μL	10-11 min
3		Fine wire	Bright sky	0, 43 sec
4		Grating	0.006 μL	20-30 min
5		Grating	30, 2 mL	0, 5-1 min
6	Cat	Grating	37, 8 ft. cand.	0, 45-1 min
7	Monkey	Grating	3.85 mL	0, 95 min
8	Rat, albino	Grating		56 min
9	pigmented	Grating		26 min
10	Chick	Grating	3.85 mL	4, 07 min
11	Pigeon	Grating	14, 4 ft. cand.	0,38-0.5 min
12	Lizard	Grating	Lowest I[1]	0, 5-1[0]
13		Grating	Highest I[1]	1, 3-11, 5 min
14	Frog	Pendulum	29, 4 min	3.5
15	Crab, fidler	Dark line	263 ft. cand.	3, 87[0]
16	Bee	Grating	100 mL	0, 9-1, 0[0]
17		2 cm square[2]	Daylight	2, 8[0]
18	Fly, fruit	Dark line	14, 6 mL	9, 28[0]

[1] Intensity.
[2] At 40 cm.

D: The Stiles-Crawford Effect[1]

Rays entering the eye near the edge of the pupil are less effective than rays entering near the center. Their relative effectiveness is denoted by η: η=1-0.0850 x^2 + 0.0020 x^4, where x is the distance (mm) from the center of the pupil.

	Distance mm	η for Double Rays	Pupil Diameter mm	η for Light Filling Pupil
1	0	1.000		
2	0.5	0.980		
3	1.0	0.917	2.0	0.958
4			2.5	0.935
5	1.5	0.819	3.0	0.908
6			3.5	0.876
7	2.0	0.692	4.0	0.841
8			4.5	0.802
9	2.5	0.548	5.0	0.761
10			5.5	0.717
11	3.0	0.397	6.0	0.672
12			6.5	0.627
13	3.5	0.260	7.0	0.580
14			7.5	0.536
15	4.0	0.152	8.0	0.492

[1] Occurs only in cone vision.

Part XIV: CONVERSION FACTORS FOR BRIGHTNESS (LUMINANCE AND LUMINOUS EMITTANCE) UNITS

Value in unit in left hand column times the conversion factor equals the value in unit shown at the top of the column.

	Units	C/sq mm	C/sq cm	C/sq m	Stilb (H)	C/sq in.	C/sq ft	L	mL	µL	m$_L$L	Apostilb(H)	Ft-L	Photons[2]
1	Candles per square millimeter	1	$1x10^2$	$1x10^6$	$1.111x10^2$	$6.452x10^2$	$9.290x10^4$	$3.142x10^6$	$3.142x10^9$	$3.142x10^{12}$	$3.142x10^{15}$	$3.491x10^6$	$2.919x10^5$	$7.854x10^5$
2	Candles per square centimeter (C.I.E. Stilb)	$1x10^{-2}$	1	$1x10^4$	1.111	6.452	$9.290x10^2$	3.142	$3.142x10^3$	$3.142x10^6$	$3.142x10^9$	$3.491x10^4$	$2.919x10^3$	$7.854x10^3$
3	Candles per square meter	$1x10^{-6}$	$1x10^{-4}$	1	$1.111x10^{-4}$	$6.452x10^{-4}$	$9.290x10^{-2}$	$3.142x10^{-4}$	$3.142x10^{-1}$	$3.142x10^2$	$3.142x10^5$	3.491	$2.919x10^{-1}$	$7.854x10^{-1}$
4	Hefner candles per square centimeter (Stilb (H))	$9.0x10^{-3}$	$9.0x10^{-1}$	$9.0x10^3$	1	5.806	$8.361x10^2$	2.828	$2.828x10^3$	$2.828x10^6$	$2.828x10^9$	$3.142x10^4$	$2.627x10^3$	$7.069x10^3$
5	Candles per square inch	$1.550x10^{-3}$	$1.550x10^{-1}$	$1.550x10^3$	$1.722x10^{-1}$	1	$1.440x10^2$	$4.869x10^{-4}$	$4.869x10^{-1}$	$4.869x10^2$	$4.869x10^5$	$5.411x10^3$	$4.524x10^2$	$1.217x10^3$
6	Candles per square foot	$1.076x10^{-5}$	$1.076x10^{-3}$	$1.076x10$	$1.196x10^{-3}$	$6.944x10^{-3}$	1	3.382	$3.382x10^3$	$3.382x10^6$	$3.382x10^9$	$3.758x10$	3.142	8.454
7	Lamberts (equivalent centimeter candles, apparent lumens per square centimeter)	$3.183x10^{-3}$	$3.183x10^{-1}$	$3.183x10^3$	$3.537x10^{-1}$	2.054	$2.957x10^2$	1	$1x10^3$	$1x10^6$	$1x10^9$	$1.111x10^4$	$9.290x10^2$	$2.500x10^3$
8	Millilamberts	$3.183x10^{-6}$	$3.183x10^{-4}$	3.183	$3.537x10^{-4}$	$2.054x10^{-3}$	$2.957x10^{-1}$	$1x10^{-3}$	1	$1x10^3$	$1x10^6$	$1.111x10$	$9.290x10^{-1}$	2.500
9	Microlamberts	$3.183x10^{-9}$	$3.183x10^{-7}$	$3.183x10^{-3}$	$3.537x10^{-7}$	$2.054x10^{-6}$	$2.957x10^{-4}$	$1x10^{-6}$	$1x10^{-3}$	1	$1x10^3$	$1.111x10^{-2}$	$9.290x10^{-4}$	$2.500x10^{-3}$
10	Milli-microlamberts (micro-millilamberts)	$3.183x10^{-12}$	$3.183x10^{-10}$	$3.183x10^{-6}$	$3.537x10^{-10}$	$2.054x10^{-9}$	$2.957x10^{-7}$	$1x10^{-9}$	$1x10^{-6}$	$1x10^{-3}$	1	$1.111x10^{-5}$	$9.290x10^{-7}$	$2.500x10^{-6}$
11	Apostilb (Hefner lumens per square foot)	$2.864x10^{-7}$	$2.864x10^{-5}$	$2.864x10^{-1}$	$3.183x10^{-5}$	$1.848x10^{-4}$	$2.661x10^{-2}$	$9.0x10^{-5}$	$9.0x10^{-2}$	$9.0x10$	$9.0x10^4$	1	$8.360x10^{-2}$	2.249
12	Foot-lamberts (equivalent foot candles; apparent foot candles; apparent lumens per square foot)	$3.426x10^{-6}$	$3.426x10^{-4}$	3.426	$3.807x10^{-4}$	$2.210x10^{-3}$	$3.183x10^{-1}$	$1.076x10^{-3}$	1.076	$1.076x10^3$	$1.076x10^6$	1.196x10	1	2.691
13	Photons[3]	$1.273x10^{-6}$	$1.273x10^{-4}$	1.273	$1.414x10^{-4}$	$8.213x10^{-4}$	$1.183x10^{-1}$	$4.000x10^{-4}$	$4.000x10^{-1}$	$4.000x10^2$	$4.000x10^5$	$4.444x10$	$3.716x10^{-1}$	1

/1/ In converting measures of brightness into photons, it is necessary to multiply the conversion factor by the square of the pupil diameter in millimeters. /2/ In converting photons to measures of brightness, it is necessary to divide the conversion factor by the square of the pupil diameter in millimeters.

Part XV: MISCELLANEOUS

A: Characteristic Luminances

Values in parentheses are ranges.

	Specification	Luminance ft-L
1	Noon sun on snow	10, 000
2	Hazy sky	1, 000
3	Foliage in landscape	(100-400)
4	Living room walls	(7-10)
5	Television screens in homes	(3, 5-10)
6	Motion pictures (theater)	1, 4(0, 4-5)
7	Drive-in	0, 7(0, 1-2, 2)
8	Photopic vision	>0, 01
9	Mesopic vision	(0, 001-0, 01)
10	Scotopic vision	<0, 001
11	Cones take over	0, 008a
12	Rods take over	0, 008a
13	Lower limit of useful color vision	0, 019a
14	Night automobile driving	(0, 003-4)
15	Asphalt roads	(0, 045-1, 1)
16	Cement roads	(0, 08-3, 2)
17	Pedestrian on road	(0, 012-0, 35)
18	Moonlight	0, 01
19	Clear starlight, no moon	0, 0001
20	Hazy starlight, no moon	0, 00001
21	Threshold	0, 00001

/1/ Foot-lamberts.

B: Color Temperatures

	Source	Degrees Kelvin
1	Candle	1900
2	Carbon filament lamp	2100
3	Gas-filled lamp, 40 watt	2700
4	60 watt	2800
5	100 watt	2870
6	1000 watt	3020
7	Ribbon filament lamp, 108 w	2950
8	CIE[1] source A	2854
9	Fluorescent "Warm White"	3000
10	Photoflood	3400
11	Carbon (solid) arc	3750
12	Fluorescent "Cool White"	4500
13	Average noon sunlight	5000
14	CIE[1] source B	4870
15	Carbon (sunshine) arc	6260
16	Fluorescent "Daylight"	6500
17	Overcast sky	6500
18	CIE[1] source C	6740
19	Light overcast sky	7500
20	Hazy blue sky	9000
21	Clear blue sky	25000

/1/ Commission Internationale de l'Eclairage. Source A is characteristic of tungsten light. source B of sunlight and source C of daylight. For details see Hardy, A. C., "Handbook of Colorimetry." Cambridge, Mass.: Technology Press, 1939.

Part XVI: GLOSSARY

APHAKIC. Destitute of the lens of the eye.

APOSTILB. 9×10^{-2} mL (see also LAMBERT).

CANDLE (C). Unit of luminous intensity defined by reference platinum standard.

CANDLEPOWER. Luminous intensity (I) expressed in candles. $I = dF/d\omega$, where F is luminous flux and ω is solid angle in steradians (see LUMEN).

DECIBEL. A logarithmic measure of the ratio between two quantities. The number of decibels denoting the ratio is 10 times the logarithm to the base 10 of the ratio.

DIOPTER. Refractive power of a lens (reciprocal of focal length, expressed in meters).

ERG. Energy of 1 dyne through 1 cm.

FLUX. Time rate of flow of light.

FOOT-CANDLE (see FOOT-LAMBERT). Unit of illumination (lumen/sq ft).

FOOT-LAMBERT (ft-L). 1 ft-L = $1/\pi$ candles/sq ft, and is the same as the apparent foot-candle, and numerically equal to the equivalent foot-candle.

ILLUMINATION (E). The density of luminous flux on a surface. $E = dF/dA$, where A is area.

INTENSITY (I). Light-giving power of a source of light (see CANDLEPOWER).

LAMBERT (L). Unit of luminance equal to $1/\pi$ candles/sq cm. It is equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting 1 lumen/sq cm.

1 Apostilb (Blondel) = 9×10^{-2} mL.

LUMEN (lm). Unit of luminous flux; it is equal to the flux through a unit solid angle (steradian) from a uniform point source of one candle.

LUMINANCE (B). Photometric brightness. It is the luminous intensity (I) of any surface in a given direction per unit of projected area of the surface as viewed from that direction. $B = dI\ (dA \cos \theta)$, where A = surface area, and θ = angle between direction of observation and 90° line to the surface.

MESOPIC. Pertaining to vision intermediate between photopic and scotopic (q.v.).

PHOTON (TROLAND). Retinal illumination for 1 sq mm of pupil area from a luminance of 1 c/sq m.

PHOTOPIC. Pertaining to vision in bright light.

SCOTOPIC. Pertaining to vision in dim light.

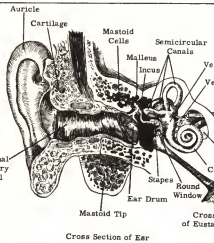
STILB. Unit of luminance equal to 1 C/sq m.

TROLAND (see PHOTON).

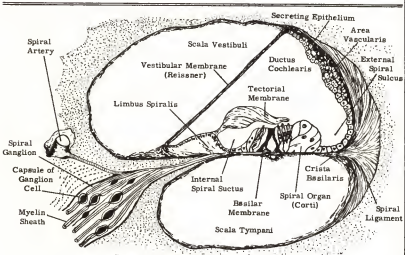
VISUAL ACUITY (V.A.). Reciprocal of angle (1' arc) between 2 black bars just visibly separate.

λ = Wave length.

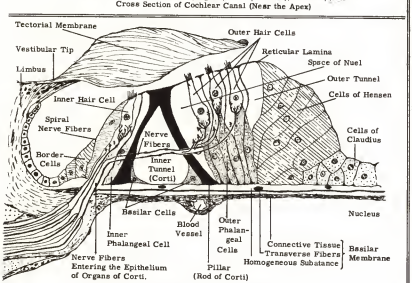
Part I: MORPHOLOGY OF THE EAR: MAN



Cross Section of Ear



Cross Section of Cochlear Canal (Near the Apex)



Cross Section of Spinal Organ (Papilla) or Organ of Corti

The external auditory canal extends inward (medially) to the tympanic- or drum-membrane. Medial to this, embedded in the bone, lies the irregular air chamber, the middle ear, and medial to the latter is the fluid-filled inner ear or labyrinth. The tympanic membrane is set in the lateral (external) wall of the middle ear, opposite the oval and round windows in the medial wall. Positioned across the chamber from the tympanic membrane to the oval window are the three ossicles (malleus, incus, and stapes), to which are attached the tensor tympanic and stapedial muscles. The handle of the malleus is attached to the drum. The incus is pinned at its outer end to the head of the malleus by a flexible joint, and the stapes in turn articulates with the incus. The footplate of the stapes fits into the oval window and is joined to the bony window around its edge by an elastic ligament. The round window is an opening in the bony labyrinth closed by a membrane. The ear receives sound waves on the drum; the vibrations are conducted by the ossicles and are transmitted through the oval window to the fluid and sensory elements in the inner ear (ultimately to the round window). The inner ear consists of the osseous labyrinth, a complicated group of communicating cavities in the bone (the vestibule adjoining the middle ear, the cochlea, and the semicircular canals) and the membranous labyrinth contained in and concentric with the osseous labyrinth. The membranous labyrinth consists of the semicircular canal, utricle, sacculeand membranous cochlea (ductus cochlearis, scala media). A clear fluid, the perilymph, surrounds the membranous labyrinth; within the membranous labyrinth is the endolymph. (The semicircular canals, utricle, and saccule are involved in equilibrium and are not considered here.) The bony cochlea, a short cone resembling a small shell, has in it the sense organ for sound perception (organ of Corti, papilla basilaris). Its bony spiral tube is divided by the spiral (bony) lamina, an incomplete partition which is completed by the ductus cochlearis, thus making three tubes, the scala vestibuli, the scala media (ductus cochlearis) and the scala tympani. The scala media has the following structures: Reissner's membrane separating it from the scala vestibule, the stria vascularis (secretory organ), the tectorial membrane resting on the organ of Corti (papilla basilaris), the organ of Corti consisting of supporting cells, pillar cells (tunnel of Corti) and external and internal hair cells (neuro-sensory elements). These structures rest on the basilar membrane which separates it from the scala tympani. The cochlear division of the 8th nerve enters the modiolus of the cochlea to form the spiral ganglion. The dendrites of the ganglion cells are distributed to the spiral organ of Corti, supported by the basilar membrane. The axons of the ganglion cells go to the medulla.

Part II: COMPARATIVE MORPHOLOGY OF AUDITORY MECHANISMS

	Species	Outer Ear			Tympanic Membrane			Middle Ear								
		External Canal						Cavity	Malleus		Incus	Stapes				
		Opening Area sq cm	Length cm	Volume ml	Diameter mm	Area sq mm	Thickness mm	Volume ml	Weight mg	Length Total mm	Weight mg	Weight mg.	Footplate Length mm	Footplate Width mm	Footplate Area sq mm	
1	Man	0.3-0.5	2.3-3.0	1.04	8-10	56-85	0.1	2	23-27	7.6-9.1	25-32	2.0-4.3	2.6-3.4	1.1-1.7	2.6-3.7	
2	Cat				5.5-8.6	32-48	0.03		10-11.4		3-4.5	0.2-0.9	1.6	1	1.1-1.3	
3	Dog															
4	Guinea pig					23-28									0.8-0.9	

	Species	Middle Ear (concluded)				Inner Ear									
		Muscles						Cochlea							
		Tensor Tympani		Stapedius		Oval Window Area sq mm	Round Window Area sq mm			Scala Vestibuli		Scala Tympani		Scala Media	
		Cross Section sq mm	Length mm	Cross Section sq mm	Length mm			Turns no.	Volume cu mm	Volume cu mm	Max. Diam. mm	Volume cu mm	Area Helicotreme[1] sq mm	Volume cu mm	Length mm
1	Man	4.8-6.9	23-26	4.9	6.3	2.0-3.7	2	2.2-2.9	98	54	3.5	37	0.08-0.2	6.7	35
2	Cat					1.1-1.3	2.8-3.3	3+			2.7				25
3	Dog							3.2			3.0				16-17
4	Guinea pig					1.4	1.0	4							18.8

	Species	Inner Ear (concluded)				Organ of Corti							
		Cochlea (concluded)					Inner Hair Cells		Outer Hair Cells				
		Basilar Membrane				Cross Sectional Area sq mm	no.	Height mm	no.	Height mm	Inner Pillar Cells no.	Outer Pillar Cells no.	Total Ganglion Cells no.
		Length mm	Thickness mm		Fibers no.								
1	Man	25-35	<0.003		24000	0.005-0.022[2]	3500	0.034	20000	0.028-0.064[3]	5600	3850	30500
2	Cat	19-25			15700	0.005-0.020[3]	2600	0.03	9900		4700	3300	
3	Dog	14-16			10500[4]		1600	0.03	6100	0.03-0.036[3]	2800	1940	
4	Guinea pig	18.8	0.007-0.0013[2]			0.012-0.017[5]							

/1/ Communicating part between scala tympani and scala vestibuli. /2/ From base to apex. /3/ Measurement made at midpoint of the length of the basilar membrane. /4/ The tympanic layer. /5/ The maximum is for a point near the apex of the cochlea; at the extreme apex the area diminishes to 0.015 sq mm.

Part III: COMPARATIVE AUDITORY SYSTEMS

	Species	Organ Type	Location	Accessory Structures
			Vertebrates	
1	Man	Organ of Corti. Pillars, tunnel, outer and inner hair cells, Hensen's cells, Claudius' cells, tectorium, Reissner's membrane.	Cochlea, 2½ to 3 turns.	Mastoid tip well developed. Mastoid area more or less pneumatic in adult. Apex pneumatic, semipneumatic, or containing either fatty or hemopoietic marrow. Stapes with posterior crus bowed. Arachnoid tissue fills aqueduct.
2	Bat	Organ of Corti, with tall pillars and stiff rod spiralling in basilar membrane in floor of tunnel.	Cochlea, 2 turns. Fibers of VIIIth cochlear branch pass straight up modiolus to apical ganglion cells. Some species spiral.	Middle ear muscles large, especially tensor tympani, with heavy nerve supply. Stapediovestibular ligament composed of discrete fiber cells. Cartilaginous trap door for closing external ear. Drum membrane very thin. Stapedius muscle unseparated by bone from jaw muscles, i.e., no bony enclosure posteriorly for middle ear. No bulla, mastoid or pneumatization. Large supply of fat in bones and among head muscles. Stapedial artery present in some species.
3	Cat and dog	Organ of Corti; no unique characteristics described.	Cochlea, 3 turns.	Bulla divided into 2 compartments separating oval and round windows. Middle ear muscles relatively large. Superior sinus of Eustachian tube widely patent. Wide cochlear aqueduct.
4	Guinea pig	Well-developed organ of Corti. High or tall Hensen's cells.	Cochlea, 4½ turns. Spiral ganglion follows through modiolus to apex.	Persistent stapedial artery and bony bar. Middle ear competely enclosed by bulla. Coils of cochlea exposed in molded form on medial wall of middle ear. Wide cochlear aqueduct.
5	Monkey	Spiral organ of Corti.	Cochlea, 2¾ turns.	Middle ear, mastoid and petrous apex completely enclosed in bone. No mastoid tip developed. Pneumatization extreme in both mastoid and apex. Bony Eustachian tube difficult to identify because of pneumatization of apex. Internal carotid artery courses through apex. No stapedial artery. Long bony external auditory canal. Cochlear aqueduct narrow.
6	Opossum	Spiral organ of Corti rests on basilar membrane.	Cochlea, 2 turns. Ganglion follows through modiolus to top coil, but is untwisted.	Incipient bulla. Membrana tympani on half-shell of bone. No bony external auditory canal. Ossicles small and fragile. Styloid process participates in articulation near head of stapes. Stapedius muscle large (derived from depressor mandibulae), occupying whole posterior wall of middle ear. Tensor tympany small (derived from pterygoid). Malleus fan-shaped anterior process. VIIth nerve passes uncovered by bone through middle ear and emerges at level of round window. Cochlear aqueduct is Y-shaped, one limb entering scala tympani and one directed toward middle ear. Large IXth ganglion in floor of middle ear.

Part III: COMPARATIVE AUDITORY SYSTEMS (Concluded)

	Species	Organ Type	Location	Accessory Structures
			Vertebrates (continued)	
7	Platypus[1]	Organ of Corti. Lagena sense organ.	Lagena. Incipient cochlea.	Recessus scala tympani narrows into funnel-shaped tube to form cochlear aqueduct.
8	Birds	Sensory cells bathed in fluid. Papilla basilaris.	Papilla lagena, basilaris and, neglecta. Papilla lagena elongated. Developed tegmentum vasculosum. Saccule reduced. No crus commune. Superior semicircular canal large and encircling others. Posterior canal smallest and communicating perilymph with horizontal.	Membrana tympani, columella, Eustachian tube, oval and round windows. Round window separates perilymph and intracranial arachnoid spaces from middle ear. Single columella. First appearance of external ear.[2]
9	Turtle		Papilla lagena, basilaris, and neglecta. Shows mound of Corti.	Membrana tympani, columella of two articulating pieces, Eustachian tube, oval and round windows. Latter separates perilymph and arachnoid spaces from middle ear.
10	Frog			Membrana tympani, columella, Eustachian tube, oval and round windows. Latter separates perilymph and intracranial arachnoid spaces from middle ear.
11	Toad[3]	Also, probably some sensation through skin of foot pads.	End-organs as in fish.	Vestibulo-scapular conduction through forefeet. Vestibulo-squamosal conduction direct from ground.
12	Fish	Sensory hair cells bathed in fluid. Lagena saccule.	Lateral line organs for slow vibrations. Labyrinth in head, bilateral, developed from lateral line organs. Cristae of 3 semicircular canals in 3 planes of space. Macula of utricle. Lagena and macula of very large saccule. Large otoliths. Papilla neglecta present in most fishes.	Forerunner of middle ear in carp, goldfish, catfish, etc. Weberian ossicles. Oval window.
			Invertebrates	
13	Cricket	Membrani tympani. Sensory cells of graded sizes.	Front leg below knee. May be second one in 2nd abdominal section.	
14	Grasshopper[4]	Membrani tympani connected with leg tracheal vesicles. Sensory cells of graded sizes.	Front segment of abdomen.	
15	Grasshopper[5]	Membrani tympani with external ear and ear slit. Sensory cells of graded sizes.	Tibia of foreleg.	

/1/ Duckbill. /2/ External ear of rooster can be closed when crowing. /3/ Tree toad; also salamander. /4/ Short antennae. /5/ Long antennae, Katydid.

Part IV: FUNCTIONS OF AUDITORY COMPONENTS: VERTEBRATES

	Species	Segment	Component	Function
1	Man[1], all mammals	External ear	Auricle.	Collects sound waves. Protects ear mechanism.
			External ear canal.	Passageway for sound waves.
		Middle ear	Ear drum (tympanic membrane).	Picks up sound waves and starts rocking of ossicles.
			Ossicles: malleus, incus, stapes.	Rocking motion transmits sound waves to perilymph and membranous cochlea through oval window.
			Eustachian tube.	Carries air from nasopharynx to middle ear.
			Antrum, mastoid cells.	Lightens skull, helps maintain air on medial side of drum.
		Internal ear	Osseous labyrinth: vestibule; horizontal semicircular canal; anterior and posterior vertical semicircular canals. Bony cochlea.	Protects membranous labyrinth.
			Membranous labyrinth: utricle, semicircular canals attached; saccule, cochlea attached; 3 semicircular canals.	Static equilibrium. Orientation in space.
			Cochlea: basilar membrane, organ of Corti.	Equilibrium, in motion (canals).
				Organ of hearing.
2	Birds and reptiles[2]	External ear	Auditory meatus.	
		Middle ear	Tympanic membrane, columella[3].	Transmits sound.
		Internal ear	Utricle, lagena saccule, papilla basilaris.	Dual function of equilibrium and hearing.
3	Amphibians	No external ear		
		Middle ear	Tympanic membrane, columella[4].	Transmits sound.
		Internal ear	3 semicircular canals. Vestibule: utricle, lagena saccule, papilla basilaris.	Dual function of equilibrium and primitive auditory organ.
4	Fishes	No external ear		
		No middle ear		
		Internal ear	3 semicircular canals[5]. Vestibule: utricle, lagena saccule.	Dual function of equilibrium and primitive auditory organ.

/1/ Cochlea highly developed. In all except aquatic mammals, middle ear has three ossicles. External ear present. /2/ Bird organs are similar in structure to those of reptiles, including basilar membrane. Tympanic organs also have hairs beneath the tympanum. /3/ Two bones, inner one acts as stapes. No middle ear in snakes. /4/ Bony rod, action similar to stapes. /5/ Higher fishes have three canals, hagfish one, and lamprey two.

Part V: HEARING THRESHOLDS FOR PURE TONES: MAMMALS

The least "strength" of a given stimulus that can just elicit a response from an organism or its parts is the threshold for the type of stimulation employed. For the sense of hearing, the "strength" (intensity) of a sound stimulus is expressed in terms of the rate of flow of sound energy at the hearing point. For binaural hearing, this is the midpoint of the position of the listener's head when the head is placed in the sound field. The unit of power (rate of energy flow) is commonly watts/sq cm. Measurements of hearing are often made, however, in terms of sound-wave pressure (dynes/sq cm) in the air at the hearing point. As the rate of energy flow is proportional to the square of the sound pressure, both are convertible to the decibel (db) scale. The least sound pressure (dynes/sq cm) at which a tone having a frequency of 1000 cycles/sec (cps) can be heard by a human observer is approximately 0.0002 dynes/sq cm. This value is used as a basis for comparison of sound intensity levels, serving as the zero reference level for a logarithmic intensity scale. The unit of this scale is the db. The intensity level of sound, in db, is 10 x the $\log_{10}$ of the ratio of the intensity of this sound to the reference intensity. As the intensity is also proportional to the square of the sound pressure, the level of a sound in db can be calculated from sound pressure in dynes/sq cm by the formula db = 20 log p_1/p_2, where p_1 is the pressure of a sound of a given frequency, and p_2 is 0.0002 dynes/sq cm (the threshold pressure of a 1000 cps tone). Negative values for decibels indicate that less energy is required to make the sound audible than is required for a tone of 1000 cps.

	Sound Wave Frequency[1]	Man[2]	Cat	Chimpanzee	Dog	Guinea Pig	Monkey	Rat
	cps	db	db	db	db	db	db	db
1	64	46				60	45	
2	100	37	38		34			
3	128	30		20		41	20	
4	200	23	24		21			
5	256	16		8		26	10	
6	400	10	9		9			
7	500	6	6		8		7	
8	512	5		-3		11		65
9	1,000	0	-1		1		-3	
10	1,024	0		-10		2		41
11	2,000	-4	-2		-3		-5	
12	2,048	-5		-14		18		40
13	2,896	-7						31
14	3,000	-8	-7		-7			
15	4,000	-8	-6		-6		3	
16	4,096	-7		-6		14		30
17	5,000	-4	-8		-10			
18	5,792	1						30
19	8,000	7	-7		-3		-14	
20	8,192	8		-9		34		-14
21	10,007	9	-7		-6			
22	11,584	10						0
23	14,000	13	-9		-5			
24	16,000	20	-4		2			

/1/ Each frequency corresponds to a different pure tone. /2/ The sound is generated at intensity just sufficient to be heard binaurally, the experimental subject is then removed, and the intensity at the hearing point is measured.

Part VI: RANGE OF HEARING: ANIMALS

Unless otherwise indicated, values are based upon changed behavior of the intact animal in response to tonal stimuli. The data, however, are inhomogenous, and the values are not strictly comparable with one another because of different criteria used in determining the lower and upper limits. The limits are not actually single numbers as they depend both on the intensity of the stimulus and the endpoint chosen to define "hearing."

	Species	Frequency Limit	
		Lower	Upper
		cps	
1	Man	15[1]	20,000[1]
2	Bat	30[2]	98,000[2]
3	Cat	30[2]	45,000[3]
4	Chimpanzee		33,300
5	Dog		40,000
6	Dolphin, Tursiops	100	130,000[4]
7	Guinea pig		40,000
8	Monkey		33,600
9	Mouse, deer	500	95,000
10	Mouse, harvest		17,500
11	Opossum	100	19,000[3]
12	Rat		40,000
13	Pigeon	100	12,000
14	Alligator		340
15	Turtle		1,200
16	Axolotl		240
17	Frog	50	10,000
18	Catfish		13,000
19	Characinidae		10,000
20	Goldfish		2,700[4]
21	Minnow		7,000
22	Cricket (Acridium aegyptium)		20,000
23	Cricket (Gryllus assimilis)	300	8,000
24	Grasshopper (Arphia sulfurea)	300	20,000
25	Katydid (Pterophylla camelliifolia)	430	45,000[2]

/1/ At the lower end the sense of hearing merges into the sense of feeling and vibration. On the musical scale (equal tempered chromatic), the note low C (C_0) has a frequency of 16, middle C (C_4, four octaves higher) 256, middle A (American Standard Pitch) 440, and high C (C_8) 4186. /2/ By recording electrical potentials from the region of the sensory organ, does not necessarily represent the capacities of the entire auditory system. /3/ Electrical responses of the cochlea up to 30,000 cps have been reported. /4/ At least as high as this figure.

Part VII: PURE TONES OF EQUAL LOUDNESS: MAN

The greater the intensity of a pure tone, the greater is its loudness up to the level of discomfort or pain. However, the loudness of a sound is a subjective estimate, whereas its intensity is measured objectively. In general, two tones of equal intensity but different frequency are not necessarily equally loud to the hearer. Each successive column, 10-120, contains values that are equal in loudness in the same column, but louder than values in the preceding column. The intensity levels for 1000 cps (Line 9) have been used as a scale of reference and appear at the head of each column.

	Pure Tone	10	20	30	40	50	60	70	80	90	100	110	120	Threshold of Feeling	
	cps	db	db	db	db	db	db	db	db	db	db	db	db	db	cps
1	Thirty	5	9	12	15	17	20	22	25	29	36	46	64	82	35
2	Fifty	5	11	15	18	22	25	29	32	38	46	57	72	92	
3	Seventy	6	12	16	21	25	28	33	37	44	53	65	80	94	75
4	One hundred	7	14	19	24	28	33	38	44	51	62	72	85	101	
5	Two hundred	8	16	23	29	37	44	51	58	67	77	87	100	109	
6	Three hundred	8	17	25	32	40	48	57	66	75	85	95	107	116	400
7	Five hundred	10	19	28	36	45	54	65	74	84	95	105	115		
8	Seven hundred	11	20	30	39	48	59	69	79	89	99	110	120	130	800
9	One thousand	10	20	30	40	50	60	70	80	90	100	110	120		
10	Two thousand	10	21	32	43	53	64	74	83	92	100	110	118	132	1500
11	Three thousand	10	21	32	43	54	65	74	83	91	100	109	118	133	3100
12	Five thousand	11	23	34	44	55	65	74	82	90	99	106	115		
13	Seven thousand	10	21	32	44	56	65	74	83	90	98	105	112	125	6500
14	Ten thousand	10	21	32	43	55	64	74	82	90	96	104	111		

	Animal	End Organ or Region of Body	Substance	Medium[1]	Method[2]	Mean or Median Threshold
1	Tongue worm	General integument	HCl	SW	W	0.002N
2	(Balanglossus sp)		NaOH or KOH	SW	W	0.0025N
3			KCl	SW	W	0.005N
4			Quinine	SW	W	0.001M
5	Tunicate	Oral siphon	HCl	SW	W	0.0016N
6	(Ascidia atra)		Formic acid	SW	W	0.0018N
7			NaOH or acetic acid	SW	W	0.010N
8			NH_4OH	SW	W	0.015N
9			KSCN	SW	W	0.10N
10			K acetate	SW	W	0.15N
11			KCl	SW	W	0.20N
12			NH_4Cl	SW	W	0.30N
13			NaCl	SW	W	0.40N
14			Strychnine	SW	W	0.00005M
15			Morphine[3]	SW	W	0.001M
16			Quinine	SW	W	0.004M
17			Ethyl ether[4]	SW	W	0.02M
18			Ethyl alcohol	SW	W	0.75M
19	Lancelet	Mouth	HCl	SW	W	0.002N
20	(Amphioxus)	Mid-trunk	KCl	SW	W	0.10N
21		Tail	HCl	SW	W	0.01N
22	Lamprey	Mouth	HCl	SW	W	0.008N
23	(Petromyzon sp)		NaOH	SW	W	0.001N
24	ammocoetes larvae		NaCl	SW	W	0.025N
25			Quinine	SW	W	0.0016M
26		Mid-trunk	NaOH	SW	W	0.01N
27			HCl or NaCl	SW	W	0.05N
28			Quinine	SW	W	0.10M
29		Tail	NaOH	SW	W	0.002N
30			HCl	SW	W	0.025N
31			NaCl	SW	W	1.0N
32			Quinine	SW	W	0.05M
33	Dogfish, smooth	Mouth	NaOH	SW	W	0.01N
34	(Mustelus sp)		HCl	SW	W	0.013N
35		Mid-trunk	HCl	SW	W	0.02N
36			NaOH[5]	SW	W	0.05N
37		Tail	HCl	SW	W	0.025N
38	Catfish	Mouth	NaOH	SW	W	0.01N
39	(Anurus sp)		NaCl	SW	W	0.02N
40			HCl	SW	W	0.05N
41			Quinine	SW	W	0.007M
42		Mid-trunk	HCl	SW	W	0.02N
43			NaOH[5]	SW	W	0.05N
44		Tail	HCl	SW	W	0.025N
45	Rat	Tongue (taste buds)	NaCl	FW	E	0.0081% (0.0075-0.0095%)
46	(Rattus rattus		NaCl	FW	R	0.05%
47	norvegicus, and		$HgCl_2$	FW	R	0.004% (0.001-0.007%)
48	var. albinus		As_2O_3	FW	R	0.0065% (0.002-0.02%)
49			Glucose	FW	A	0.20% (0.1-0.4%)
50			Galactose	FW	A	1.6% (0.5-2.8%)
51			Lactose	FW	R	4.8% (2.8-6.5%)
52			Maltose	FW	A	0.06% (0.04-0.08%)
53			Sucrose	FW	A	0.57% (0.1-0.8%)
54			Quinine HCl	FW	A	0.00005% (0.000012-0.0002%)
55			Quinine HCl	FW	R	0.0003% (0.0001-0.0012%)
56			Quinine SO_4	FW	R	0.00072% (0.00038-0.0016%)
57			Phenylthiocarbamide	FW	R	0.0003% (0.00005-0.02%)
58			a-Naphthylthiourea	FW	R	0.001% (0.0005-0.0025%)
59			Phenylthiourea	FW	R	0.002% (0.0001-0.008%)
60			Thiosemicarbazide	FW	R	0.0023% (0.0005-0.005%)
61			Strychnine SO_4	FW	R	0.0068% (0.005-0.02%)
62	Adrenalectomized		NaCl	FW	E	0.0104% (0.0048-0.017%)
63	Rabbit, European	Tongue (taste buds)	HNO_3	FW	R	0.085N
64	(Oryctolagus cuniculus)		HCl	FW	R	0.12N
65			H_2SO_4	FW	R	0.14N
66			Acetic acid	FW	R	0.17N
67			NaI	FW	R	0.79N
68			$NaNO_3$	FW	R	0.81N
69			NH_4Cl	FW	R	1.0N
70			KCl	FW	R	1.1N
71			Na acetate or $NaSO_4$	FW	R	1.3N
72			NaCl or $CaCl_2$	FW	R	1.4N
73			LiCl	FW	R	1.8N
74			Sucrose	FW	A	0.31M
75	Cat, domestic	Tongue (taste buds)	HCl	FW	E	0.02N(0.007-0.07N)
76	(Felis catus)		NaCl	FW	E	0.1-0.3N
77			Quinine	FW	E	0.001-0.005M
78	Monkey	Tongue (taste buds)	Quinine HCl	FW	A	0.0013%(0.0003-0.006%)
79	(Macaca mulatta)		Quinine HCl	FW	R	0.025% (0.0015-0.05%)
80	Chimpanzee	Tongue (taste buds)	Quinine HCl	FW	A	0.0003%
81	(Pan troglodytes)		Quinine HCl	FW	R	0.0062%

/1/ Dispersion medium for the stimulating substance. SW=sea water; FW=fresh water. /2/ Experimental procedure used to indicate reception. W=generalized avoidance reaction or withdrawal of part of body; E=electro-physiological methods; A=acceptance thresholds for materials offered in food or water; R=rejection thresholds. /3/ Same value for amyl alcohol. /4/ Same value for chloral hydrate. /5/ Same value for tail, NaOH.

293. TASTE AND OLFACTION THRESHOLDS: MAN

Values derived from early literature were excluded from this table. It is considered that publication of the older values might perpetuate certain ambiguities, if not errors, that have arisen in translation and recalculation. Data presented below have been selected from the more recent research publications.

Part I: TASTE THRESHOLDS

Values are lowest molar concentrations that can be distinguished as different from water alone.

	Substance	Threshold Mole/L		Substance	Threshold Mole/L
1	Formic acid	0.0018	13	n-Pentanol	0.016
2	Acetic acid	0.0028	14	n-Hexanol	0.002
3	Butyric acid	0.0035	15	n-Heptanol	0.0013
4	Valeric acid	0.0037	16	n-Octanol	0.0006
5	Tartaric acid	0.0011	17	1,2-Butanediol	0.052
6	Glutaric acid	0.00225	18	1,3-Butanediol	0.016
7	Succinic acid	0.0016	19	1,4-Butanediol	0.031
8	Lactic acid	0.0028	20	1,5-Pentanediol	0.017
9	Oxalic acid	0.0010	21	1,6-Hexanediol	0.013
10	Ethanol	0.32	22	1,8-Octanediol	0.016
11	n-Propanol	0.11	23	Ethylene glycol	0.063
12	n-Butanol	0.028	24	Trimethylene	0.037

Part II: THRESHOLDS OF TASTERS vs NON-TASTERS

Tasters are individuals relatively sensitive to phenylthiourea; non-tasters are relatively insensitive. Values are lowest molar concentrations that can be distinguished as different from water alone.

	Substance	Tasters Mole/L	Non-Tasters Mole/L
1	Urea	0.132	0.132
2	Phenylurea	0.00551	0.00551
3	Thiourea	0.00295	0.0553
4	Phenylthiourea	0.000020	0.00306
5	Diphenylthiourea	0.000013	0.000070
6	Acetylthiourea	0.000093	0.00719
7	Diacetylthiourea	0.000106	0.002068
8	Thioglyoxaline	0.000155	0.00845
9	Thio-methylhydantoin	0.000508	0.00217
10	Uracil	0.011	0.00928
11	Methyl-thiouracil	0.000296	0.001204

Part III: OLFACTION THRESHOLDS

P_{olf} = partial pressure of substance for olfactory recognition; P^o = vapor pressure of pure substance; $A_{olf} = P_{olf} \div P^o$ = the fraction of saturated vapor of substance that allows threshold recognition.

	Substance	Concentration mg/L	P_{olf} atm x 10^{-7}	P^o atm (37°C)	A_{olf} x 10^{-3}
1	Amyl acetate	0.039	90	0.013	1
2	Ethyl acetate	0.69	1760	0.23	1
3	Butyric acid	0.009	18	0.003	1
4	Ethyl ether	5.83	13,000	1.1	1
5	Chloroform	3.30	6700	0.4	2
6	Artificial musk	0.00004	0.029	0.0000013	2
7	Carbon tetrachloride	4.53	6700	0.24	3
8	Valeric acid	0.029	50	0.001	5
9	Amyl alcohol	0.225	500	0.007	7
10	Nitrobenzene	0.146	300	0.0007	40
11	Methyl salicylate	0.10	150	0.00026	60

	Substance	Threshold A_{olf} x 10^{-4}
1	Methyl alcohol	500
2	Ethyl alcohol	300
3	n-Butyl alcohol	7
4	n-Hexyl alcohol	7
5	n-Octyl alcohol	30
6	n-Decyl alcohol	200
7	n-Dodecyl alcohol	1000
8	Ethane	170
9	n-Butane	8
10	n-Pentane	10
11	n-Heptane	50
12	n-Nonane	200
13	n-Undecane	450
14	n-Butyl chloride	5
15	n-Heptyl chloride	30
16	n-Decyl chloride	100

294. PAIN SENSITIVITY: MAN

Specific thresholds of pain are necessarily arbitrary, since the variations between individuals, and within an individual under differing conditions and accommodations, are great. Widely accepted standards for measurement have not yet been achieved. Body locus of stimuli materially affects mechanical and electrical thresholds, and chemical pain stimulation is generally in proportion to the pH extreme. An accepted thermal pain threshold of 0.21 gram-calories/sec/sq cm reported (Woodson, W. E., Human Engineering Guide, 1954). The data in this table, from the research of J. D. Hardy, H. G. Wolff, and H. Goodell, are based on only limited samplings of subjects and should under no circumstances be considered standards.

Part I: PRICKING PAIN THRESHOLDS

Values are for a final skin temperature of 34°C, corrected from observed threshold values by the formula: $Q_{34} = Q + 20(T_s - 34)$, where Q_{34} = pain threshold for 34°C; Q = observed pain threshold in millicalories per second x square centimeter; and T_s = final skin temperature. Values in parentheses are estimate "h" of the 95% range (cf Introduction).

	Skin Area[1]	Final Skin Temp. °C	Pain Threshold millical.²/sec/sq cm		Skin Area[1]	Final Skin Temp. °C	Pain Threshold millical.²/sec/sq cm
1	Forehead	45.7	235(181-289)	19	Arch	44.3	200(144-256)
2	Cheek (zygoma)	44.6	210(156-264)	20	Heel	53.7	390(202-478)
3	Nose	44.8	215(151-279)	21	Heel, corneal layer		
4	Lips	44.1	200(124-276)		shaved off		250
5	Chin	45.0	220(166-274)	22	Shoulder	44.8	215(143-287)
6	Cheek	44.8	215(127-303)	23	Neck (nape)	43.8	195(147-286)
7	Nipple	43.8	200(136-264)	24	Back (upper)	43.5	185(121-249)
8	Abdomen	43.9	200(144-236)	25	Back (middle)	43.8	195(147-242)
9	Groin	43.3	185(137-233)	26	Back (lower)	42.2	160(104-216)
10	Thigh (posterior)	42.8	175(119-231)	27	Buttock	42.4	165(89-241)
11	Thigh (anterior)	42.6	170(114-226)	28	Arm (upper)	43.4	185(117-253)
12	Kneecap	42.7	175(139-211)	29	Forearm (volar)	44.4	210(146-274)
13	Popliteal space	43.5	190(150-230)	30	Forearm (outer)	44.0	200(152-248)
14	Calf	43.0	185(129-241)	31	Hand (back)	43.8	195(131-259)
15	Shin	43.9	190(146-234)	32	Finger pad	47.1	260(180-340)
16	Ankle	44.0	190(146-234)	33	Fingernail		215(185-245)
17	Foot, dorsum	43.2	180(124-236)	34	Palm, center	45.1	220(152-288)
18	Toe, dorsum	43.4	185(117-253)	35	Palm, over callus	45.6	230(158-312)

/1/ Ink-blackened skin areas exposed to radiant heat stimulus for three seconds. /2/ Millicalories = small calories/1000.

Part II: SCALE OF PRICKING PAIN INTENSITY

It is not usually possible to discriminate between stimuli less than two steps apart; therefore, for purposes of this table, the unit of pain sensation is equivalent to two steps and is designated as a dol. Ceiling pain intensity has a value of 10½ dols, as there are 21 steps between pain threshold and ceiling pain, under conditions specified.

	Stimulus, Intensity[1] millicalories²/second/sq cm	Increments of Intensity Discrimination		No. of Step	dols	Stimulus Intensity[1] millicalories²/second/sq cm	Increments of Intensity Discrimination		Step	dols
1	220	◄	Pain threshold	►		12 300	10		11th	
2	227	7		1st	1	13 310	10	90	12th	6
3	234	7	14	2nd	1	14 320	10		13th	
4	241	7		3rd		15 335	15	115	14th	7
5	248	7	28	4th	2	16 350	15		15th	
6	255	7		5th		17 365	15	145	16th	8
7	262	7	42	6th	3	18 380	15		17th	
8	269	7		7th		19 395	15	175	18th	9
9	276	7	56	8th	4	20 425	30		19th	
10	283	7		9th		21 480	55	260	20th	10
11	290	7	70	10th	5	22 640	◄	Pain ceiling	►	

/1/ Stimulus is intense radiant heat applied for three seconds to ink-blackened skin of forehead or forearm. /2/ Millicalories = small calories/1000.

Part III: PRESSURE PAIN THRESHOLDS

	Surface	Threshold[1] g/sq mm
1	Cornea	0.2
2	Conjunctiva	2
3	Abdomen	15
4	Forearm, front	20
5	Forearm, back	30
6	Calf	30
7	Back of hand	100
8	Sole of foot	200
9	Finger tip	300

/1/ Pressure applied with sharp needle.

Table adapted from data presented in E. Newton Harvey's "Bioluminescence," Academic Press, 1952.

	Groups and Typical Luminous Genera	Habitat[1]	Type of Light[2]	Knowledge of Histology[3]	Necessity for Oxygen[4]	Luciferin-Luciferase Reaction[5]	Adenosine Triphosphate Reaction[6]	Inhibition by Light[7]	Color of Fluorescence[8]	Color of Bioluminescence[9]
1	Bacteria (Photobacterium, Achromobacter, Vibrio)	M, F[10]	I	±	+	+	-	±	-	Bluish to green-ish (470, 490, 495)
2	Fungi basidiomycetes (Panus, Omphalia, Fleurotus, Polyporus, etc.)	T	I	±	+	-	-	-	-	White (528, 520)
3	Radiolaria (Thalassicola, Sphaerozoum, Collosum, Myxosphaera, Collosphaera)	M	I	±	-	-		-	-	Faint bluish
4	Dinoflagellata (Noctiluca, Ceratium, Gonyauiax, Gymnodinium, Pyrocystis, etc.)	M	I	±	+	-		±DN		White or bluish
5	Porifera (Grantia)	M	I?	-		-		-		Yellowish
6	Hydroida Hydroids (Campanuiaria, Obelia, Aglaophenia, etc.)	M	I?	-			-			Yellowish
7	Hydromedusae (Aequorea, Halistaura, Phialidium, etc.)	M	I?	-	-	-	-	-		Bluish green
8	Siphonophora (Diphyes, Hippopodius, Agalma, etc.)	M	I?	-						Faint bluish
9	Scyphomedusae (Pelagia, etc.)	M	E?	±	-	-	-	-11	-	Greenish blue
10	Pennatulacea (Cavernularia, Pennatula, Renilla, Pteroeides, etc.)	M	I	±	+	-	+,12	±13	-	Yellowish
11	Gorgonacea (Ceratosis, Primnoisis, etc.)	M	?	-						Pale lilac
12	Ctenophora (Mnemiopsis, Beroë, Pleurobrachia, Bolinopsis, Eucharis, etc.)	M	I	±	-	-	-	+	Greenish	Blue-green
13	Nemertinae (Emplectonema) Polychaeta	M	I	+						Bluish white
14	Polynoinae (Acholoë, Polynoë, Harmothoë, etc.)	M	I	+	+	-		-	Yellowish	Yellowish
15	Alciopidae (Callizonella, Corynocephalus, etc.)	M		-						Bluish
16	Tomopteridae (Tomopteris)	M	I?	±		-			-	Yellowish
17	Syllidae (Odontosyllis, etc.)	M	E	±		+				Bluish
18	Eunicidae (Onuphis)	M	I	-						Bluish green
19	Chaetopteridae (Chaetopterus, Mesochaetopterus, etc.)	M	E	+	+	-	-	-	Bluish	Bluish
20	Cirratulidae (Cirratulus, Heterocirrus, etc.)	M	E	+						Yellow-green
21	Terebellidae (Thelepus, Polycirrus)	M	E	+	+	-			-	Bluish
22	Oligochaeta (Microscolex, Eisenia, Fontodrilus, Ortochaetus, etc.)	T[14]	E	+	+	,15	-	-	Yellow-green	Yellow-green (550)
23	Nudibranchia (Plocamopherus, Phyllirhoë, Koloplocamus, etc.) Pulmonata	M	E[16]	+		-	-			Bluish white
24	Ariophantidae (Dyakia)	T	I	-						Bluish
25	Lattidae (Latia)	F	E	+		+				Bluish green
26	Prosobranchia (Planaxis)	M	I	-		-	-			Bluish
27	Bivalvia (Pholas, Rocellaria)	M	E	+	+	+	-	-		Greenish blue
28	Vampyromorpha (Vampyroteuthis) Decapod squid[17]	M	I	+						
29	Oegopsida (Watasenia, Lycoteuthis, Histioteuthis, Calliteuthis, Chiroteuthis, Cranchia, etc.)	M	I	+	+	-	-	-		Bluish[18] or yellowish
30	Myopsida (Inioteuthis, Rondeletia, Sepiola, Spirula, etc.)	M	Ba or Bp	+	+				-	Bluish[19]
31	(Heteroteuthis; Stoloteuthis)[20]	M	E	+	+	-	-	-	-	Yellowish blue
32	Ostracoda (Cypridina, Pyrocypris, Conchoecia, etc.)	M	E	+	+	+	-	+	Yellow	Blue (480-470)
33	Copepoda (Pleuromma, Leuckartia, Heterochaeta, Oncaea, etc.)	M	E	±	+	-		±DN	Greenish[21]	Greenish
34	Isopoda (Megaliga, Porcellio) Amphipoda	MT	Bp		+					Bluish
35	Gammaridea (Talitrus, Orchestia, etc.)	M	Bp		+					Bluish
36	Hyperidea (Scyphilomaceola, Streetsia, Parapronoë)	M	I?	±						Greenish yellow[22]

/1/ F = fresh water; M = marine, T=terrestrial. /2/ Bp=light emission owing to parasitic luminous bacteria; Ba=light emission owing to symbiotic luminous bacteria; E = self-luminosity with extracellular light emission from secreted material; I = self luminosity with intracellular material. /3/ + = cytology of the photogenic cell or histology of the light organ is well known; - = cytology or histology unknown; ± = further study of cytology or histology is desirable. /4/ + = dissolved molecular oxygen is necessary for light production; - = light will appear in complete absence of oxygen (Pt and H_2, or, in excess, hydrosulfite). /5/ + = positive reaction if light appears when a hot water extract of the luminous cells allowed to cool (luciferin) is mixed with a cold water extract of the luminous cells allowed to stand until the light disappears (luciferase); - = a negative reaction. /6/ + = positive reaction if a non-luminous water extract of the luminous tissue containing magnesium emits light when the sodium salt of adenosine triphosphate is added; - = a negative reaction. /7/ + = marked inhibition of luminescence of single-celled organisms or of luminescent extracts by sunlight; - = no marked inhibition; ± = some species show light inhibition, others do not; DN = day-night rhythm of luminescence such that the intact living organism does not luminesce in the daytime even if kept in the dark. /8/ - = no marked fluorescence in near ultraviolet light or after functional activity. /9/ Figures in parentheses are wave lengths of maximum emission where spectrophotometric curves are known. /10/ Some luminous bacteria live on the flesh of terrestial animals. /11/ Inhibition has been observed. /12/ Adenosine triphosphate reaction positive in Renilla Kollikeri and negative in R. reniformis. /13/ In Renilla, inhibition and no inhibition have been observed. /14/ Pontrodilus matsushimensis lives in sand, wet by the sea. /15/ Thermolabile and thermostable components demonstrated. /16/ Kaloplocamus reported to have intracellular luminescence. /17/ The location of luminous organs has been tabulated by G. Grimpe and H. Hoffman (Tab. Biol. 6:462-4, 1930). /18/ Red, white, and blue in Lycoteuthis diadema. /19/ Greenish yellow in Spirula. /20/ No luminous bacteria demonstrated in Stoloteuthis. /21/ Bluish in Oncaea. /22/ Regarding Parapronoë.

Table adapted from data presented in E. Newton Harvey's "Bioluminescence," Academic Press, 1952.

	Groups and Typical Luminous Genera	Habitat[1]	Type of Light[2]	Knowledge of Histology[3]	Necessity for Oxygen[4]	Luciferin-Luciferase Reaction[5]	Adenosine Triphosphate Reaction[6]	Inhibition by Light[7]	Color of Fluorescence[8]	Color of Bioluminescence[9]
37	Mysidacea (Gnathophausia, Mysis, Siriella, Gastroascus)	M	E	±						Greenish
38	Schizopoda (Nyctiphanes, Euphausia, Nematoscelis, etc.)	M	I	+		-			Greenish?	Bluish
	Decapod shrimp									
39	(Sergestes, Hoplophorus, etc.)	M	I	+		-	-			Greenish yellow
40	(Systellaspis, Plesiopenaeus, Heterocarpus, etc.)	M	E	+		+	-			Bluish
41	(Xyphocaridina)	F	Bp		+					Bluish
42	Diplopoda (Luminodesamus, Spirobolellus)	T	I, Bs?	-	+	-	-		Blue-green	Greenish white
43	(Trigoniulus)	T	Bp							
44	Chilopoda (Stigmatogaster, Orya, Geophilus, Scolioplanes, etc.)	T	E	+	+	-			Bluish?	Blue-green
45	Collembola (Neanura, Onychiurus, etc.)	T	I[23]	-						Blue-green or greenish yellow
46	Orthoptera (Gryllotalpa)	T	Bp?	-						Greenish white
47	Ephemerida (Caenis, Telogmodes)	T	Bp?	-						Pale blue
48	Hemiptera (Fulgora)	T	?	-						White
49	Diptera (Ceroplatus, Platyura, Arachnocampa, etc.)	T	I	*		-	-			Bluish
50	(Chironomus)	T	Bp							Greenish
51	Lepidoptera (Mamestra, Agrotis larvae, Asteroscopus adult)	T	Bp							Bluish
52	Hymenoptera (Camponotus, Iridomyrmex)	T	Bp?	-						Greenish-yellow
	Coleoptera									
53	Lampyridae (Photinus, Photuris, Lucicla, Lampyris, etc.)	TF	I	+	+	+	+	-[24]	Greenish yellow[25]	Orange (565), yellow (570), or green (550)
54	Phengodidae (Phengodes, etc.)	T	I	+	+		-	-	+, yellowish?	Yellow-green
55	Rhagophthalmidae (Dioptoma)	T	I	-						Green
56	Drilidae (Diplocladon)	T	I	-						Greenish blue
57	(Phrixothrix)	T	I	+	+	-	-	-	-	Red and yellow-green
58	Elateridae (Pyrophorus, etc.)	T	I	+	+	+	+	-[24]	Yellow	Greenish and orange (518 and 530)
59	Ophiuroidea[26] (Amphiura, Ophioscolex, Ophiopsila, etc.)	M	I	+	+	-			Yellow-green	Green
60	Enteropneusta (Ptychodera, Balanoglossus)	M	E	+	+	-	-	-DN[27]	-	Bluish or greenish
61	Tunicata (Pyrosoma, Appendicularia, Salpa, etc.)	M	I or Bs?	+		-	-	-		Various colors
62	Elasmobranchii (Etmopterus, Laemargus, Centrosyllium, etc.)	M	I	+						Greenish or white
	Teleostomi									
63	Macrouridae (Malacocephalus, Coelorhynchus, etc.)	M	Bs	+	+	+				Greenish blue (510)
64	Gadidae (Physiculus, Lotella)	M	Bs	+						Greenish blue
65	Monocentridae (Monocentris)	M	Bs	+		-		-		Weak bluish
66	Anomalopidae (Photoblepharon, Anomalops, Kryptophaneron)	M	Bs	+						Greenish blue
67	Acropomatidae (Acropoma)	M	Bs	+						Bluish white
68	Leiognathidae (Leiognathus, Gazza, Secutor)	M	Bs	+					F	Bluish white
69	Serranidae (Apogon)	M	I?	+						Bluish green
70	Cerratiodea (Dolopichthys, Cerstias, Linophryne, etc.)	M	Bs?	+						Bluish green or purplish
71	Saccopharyngidae (Saccopharanx)	M	Bs?	-						White
72	Batrachoididae (Porichthys, etc)	M	I	+						White
73	Stomiatoidea (Echiostoma, Gonostoma, Maurolicus, Polyipnus, Argyropelecus, Chauliodus, Stomius, etc.)	M	I[28]	+		-	-	-	Greenish[29]	Yellowish to greenish or bluish
74	Myctophoidea (Myctophum, Diaphus, Lampadena, Neoscopelus)	M	I	+		-	-		Greenish	Bluish or greenish

/1/ F = fresh water; M = marine; T=terrestrial. /2/ Bp=light emission owing to parasitic luminous bacteria; Bs=light emission owing to symbiotic luminous bacteria; E = self-luminosity with extracellular light emission from secreted material; I = self luminosity with intracellular material. /3/ + = cytology of the photogenic cell or histology of the light organ is well known; - = cytology or histology unknown; * = further study of cytology or histology is desirable. /4/ + = dissolved molecular oxygen is necessary for light production; - = light will appear in complete absence of oxygen (Pt and H_2, or, in excess, hydrosulfite). /5/ + = positive reaction if light appears when a hot water extract of the luminous cells allowed to cool (luciferin) is mixed with a cold water extract of the luminous cells allowed to stand until the light disappears (luciferase); - = = negative reaction. /6/ + = positive reaction if a non-luminous water extract of the luminous tissue containing magnesium emits light when the sodium salt of adenosine triphosphate is added; - = a negative reaction. /7/ + = marked inhibition of luminescence of single-celled organisms or of luminescent extracts by sunlight; - = no marked inhibition; ± = some species show light inhibition, others do not; DN = day-night rhythm of luminescence such that the intact living organism does not luminesce in the daytime even if kept in the dark. /8/ - = no marked fluorescence in near ultraviolet light or after functional activity. /9/ Figures in parentheses are wavelengths of maximum emission where spectrophotometric curves are known. /23/ It has been claimed that the light comes from a fungus in some species. /24/ Intense illumination of the luminous organ inhibits luminescence by affecting nerve stimulation. /25/ The purified luciferin is blue fluorescent in acid, yellow-green in alkali. /26/ The location of luminous organs has been tabulated by G. Grimpe (Tab. Biol. 6:449-501, 1930). /27/ In Ptychodera at Bermuda. /28/ No luminous bacteria demonstrated in Yarella or Polyipnus. /29/ Argyropelecus photophores show no marked fluorescence.

	Species	Geographic Distribution	Specialized Structures	Remarks
			Sarraceniaceae (Pitcher-plants)	
1	Darlingtonia californica	California, Oregon.	Erect, hooded, pitcher-like leaves from 1.5 to 100 cm long, lined with "nectar" glands and hairs. "Digestive" glands absent.	Cf Heliamphora.
2	Heliamphora spp[1]	Northern South America.	Pitcher-like leaves, 30-50 cm long when mature, lined with "nectar" glands and unicellular hairs. "Digestive" glands absent.	Any digestion of animal "prey" must be attributed to adventitious bacterial action because of the reported absence of digestive glands or secretions. Ability of plant to absorb products of digestion not determined.
3	Sarracenia spp[2]	Eastern North America.	Pitcher-like leaves, 10-40 cm long when mature, lined with "nectar" glands, unicellular hairs, "digestive" glands, non-cuticular "absorptive" areas present.	Absorption of liquid from pitchers has been demonstrated. pH of pitcher contents in the field varies from 2 to 8. Mature pitchers contain considerable amounts of decayed insect residues. Presence of various enzymes, i.e., maltase, lipase and proteinases, reported in pitcher liquid. Role of bacteria in digestion of animal "prey" not determined.[3]
			Nepenthaceae (Nepenthes)	
4	Nepenthes (a65 spp)[4]	Southwest Pacific to Ceylon and Madagascar.	Leaves tendril-like, up to one meter long, terminating in pitcher-like erect hooded cups 5-30 cm long. Pitchers are lined with "nectar" glands, various types of hairs, and "digestive" glands.	Cf Sarracenia.
			Droseraceae (Sundews)	
5	Aldrovanda vesiculosa	Europe, Asia, Africa, Australia.	Leaves in whorls of 8, bearing at their tips bilobed "traps" (somewhat similar to Dionaea); inner aspects of lobes bear "secreting" glands and 3 kinds of hairs.	Traps close on appropriate stimulation, as in Dionaea. Insects thus trapped disintegrate. Action of bacteria and enzymes not determined.[5]
6	Dionaea muscipula (Venus fly-trap)	Peat bogs of North and South Carolina.	Leaves bilobed, with marginal spines and six "trigger" hairs in center of upper surface. Upper leaf-surface bears "nectar" glands and "digestive" glands, both types sessile.	When an insect comes in contact with a trigger hair, the leaf-lobes close rapidly (<0.25 sec), forming with the marginal spines a box-like structure within which the "prey" may be entrapped. Closure is followed by the secretion of an acid substance in which various proteolytic enzymes have been reported. Role of bacteria in digestion uncertain. Absorption of products of digestion reported; significance on nutrition not determined.
7	Drosera (a90 spp)	World-wide.	Leaves orbiculate, spatulate or linear, 2-35 cm long, with tentacles yielding a viscid secretion.	Tentacles inflect to cover insects entrapped in tentacular secretion. Secretion contains sugars and enzymes capable of proteolysis at pH 2. Digestion independent of bacterial action; absorption not clearly demonstrated.[6]
8	Drosophyllum lusitanicum	Portugal, Spain, Morocco.	Similar to Byblis (cf below) but larger, shrubbier, leaves with stalked "mucilage" glands and sessile "digestive" glands.	Insects captured in mucilaginous secretion. Digestion by secreted enzymes reported, possibly affected by bacteria. Beneficial absorption of proteolytic products reported.
			Cephalotaceae (Cephalotus)	
9	Cephalotus follicularis	Australia.	Leaves of 2 kinds: foliage (to 15 cm) and pitcher-like (pitchers to 5 cm long, at right angle to petiole). Pitcher lined with glands and modified stomata which are secretory in function.	Insects entrapped in pitchers disintegrate; whether this is caused by bacterial action, by enzymes produced by the plant, or by both, not determined. No evidence of absorption of products of proteolysis.
			Byblidaceae	
10	Byblis gigantea, B. linifolia	Australia.	Semi-shrubs with linear leaves, 10-20 cm long, bearing stalked "mucilage" glands and sessile "digestive" glands.	Small, wingless insects live on leaves and feed on other insects entrapped by mucilage. Digestion of egg-white in contact with secretion of digestive glands reported. Role of bacteria in digestion and absorption of products of digestion not determined.
11	Roridula (2 spp)	South Africa	Leaves equipped with tentacular glands furnishing a "resinous" secretion.	Digestion by bacteria or secreted enzymes not reported. Certain insects habitually feed on entrapped "victims." Cf Byblis.
			Lentibulariaceae (Bladderworts)	
12	Genlisea (a10 spp)	Tropical Africa, South America.	Small submersed plants with "foliage" and "trapping" leaves, which are forked at tip, spirally twisted and connected with a basal bulb or receptacle. Grooves formed by twisted portion are transversely ridged and supplied with glandular hairs secreting mucilage.	Disintegrated insect remains are commonly found in grooves of leaves and in basal receptacles. Digestion or absorption of digestive products not determined.
13	Pinguicula (a30 spp)	Northern Temperate and Subarctic Zones.	Rosette plants with entire leaves bearing "mucilage" and "digestive" glands.	Small insects become entangled in mucilage secretions, and leaf margins slowly enroll. Disintegration of insects ensues. Bacterial or enzymatic action uncertain. Absorption of products of digestion not determined.[7]
14	Utricularia (a275 spp)	World-wide.	Aquatic plants bearing on submersed portions small vesicles or "bladders" lined with glandular hairs. Absorption of water within bladders leads to formation of a partial vacuum; a door closes the bladder. On the outer surface of the door are 4-6 "tripping" hairs or bristles.	When an aquatic insect encounters the tripping hair, the door opens and the inrushing water carries the insect into the bladder. After an interval the partial vacuum is reestablished, again setting the trap. Entrapped insects disintegrate and are apparently absorbed. Bacterial action not determined.
15	Biovularia (2 spp)	Antilles, South America.	Cf Utricularia.	Cf Utricularia.
16	Polypompholyx (3 spp)	Australia.	Cf Utricularia.	Cf Utricularia.

/1/ Species: H. macdonaldiae, H. minor, H. nutans, H. tatei, H. tyleri. /2/ Species: S. aduncа, S. drummondii, S. flava, S. jonesii, S. minor, S. oreophila, S. psittacina, S. purpurea, S. rubra, S. sledgii, S. variolaris. /3/ Insect larvae, especially of mosquitoes, have frequently been found growing in the pitcher liquid. This raises questions as to the proteolytic property of the plant secretions. /4/ Five distinct types of nepenthes are: N. villosa, N. lowii, N. rajah, N. hookeriana, N. rafflesiana. /5/ There is evidence that the plant can grow indefinitely on inorganic nutrients, and no evidence that organic nutrition through the capture of animals is essential for growth. /6/ Plants have survived 15 years, in aseptic culture, on inorganic nutrients + sucrose. /7/ Laplanders reported to use leaf secretion to curdle milk.

Cilia cease beating when underlying muscle contracts, resume beating when muscle relaxes.

	Ciliated Material	Chemical Factors	Results
		Protozoa	
1	Paramecium	Novocaine, 0.5%	Ciliary coordination may be interrupted; partial disappearance of metachronal activity [1], or merely slowing of rate.
2		Ions (Na, K, Li, etc.)	Reversal of ciliary beat.
		Invertebrates	
3	Actinian larvae, longitudinal band	Ca, Mg ions	Neuromuscular movement inhibited, ciliary movement stimulated.
4	Ctenophora, meridional combs	H, K, and NH_4 ions	Neuromuscular movement stimulated, then depressed; ciliary movement depressed, then recovers.
5	Veliger (Molluscs) larvae, lobes	Li and Na ions	Neuromuscular movement stimulated, ciliary movement inhibited.
6	Trochophore larvae, peristomal;		
7	Annelida larvae		
8	Nemerteans, surface	Atropine, 2%	Strong initial stimulus; actively moving after 4 hours.
9	epithelium	Curare, 2%	Strong initial stimulus; actively moving after 4 hours.
10		Ether, 2%	Cilia continued beating, undiminished for a long time.
11		Lithium chloride, 2% in sea	Cilia at rest after 15 minutes.
12		Magnesium chloride, 2% water	Muscular contraction inhibited, but not cilia.
13		Nicotine, 2%	Cilia brought to rest after a few minutes.
14		Pilocarpine, 2%	Very active ciliary movement, undiminished after 2 hours.
15		Strychnine, 2%	Ciliary movement stimulated initially, then becomes inactive.
16	Pecten yessoensus (Molluscs),	pH 3.7 ± 0.1: HCl at 13°C	
17	terminal cilia on end of gill	3.8 ± 0.4: H_3PO_4 at 20°C	
18		5.45 ± 0.15: CH_3COOH at 20°C	Stop cilia in 1 minute; order of efficiency: $H_2CO_3 > CH_3COOH > H_3PO_4 > HCl$.
19		5.5 ± 0.5: H_2CO_3 at 20°C	
20		6.15 ± 0.05: H_2CO_3 at 13°C	
21	Anodonta (Molluscs), gill	Caffeine, 2%	Ciliary movement accelerated for 3 minutes, ceased in 6 minutes.
22		Chloral hydrate, 0.5%	Cilia quiet in 4 to 5 minutes.
23		Novocaine, 1%	Cilia quiet in 9 minutes.
24		Pilocarpine HCl, 1.5%	Metrachronal activity[1] continues until cilia become quiet (2 minutes).
25		Strychnine sulfate, 1%	Cilia quiet in 10 minutes.
26		Veratrine sulfate, 1-1.5%	Metachronal activity[1] continues until cilia quickly cease movement.
		Vertebrates	
27	Frog, buccal membrane (excised)	Acetic acid vapor gas	Ciliary movement stimulated initially, then stopped.
28		Ammonia vapor, 1.5% chamber	Initial strong movement of cilia, then cessation.
29		Alcohol, amyl	Cessation of ciliary movement in 18 minutes.
30		butyl 1:10 dilution	Cessation of ciliary movement in 3 hours.
31		ethyl in normal	Cessation of ciliary movement after 30 hours.
32		methyl saline	Cessation of ciliary movement after 30 hours.
33		propyl	Cessation of ciliary movement after 25 hours.
34		Acids	Cilia brought to rest.
35		Alkalies (KOH, NaOH)	Ciliary activity slowly stimulated, then became vigorous.
36		Ions (Na, K, Li, etc.)	Reversal of ciliary beat.
37		Sodium bicarbonate, conc. vapor	Quick cessation of ciliary movement.
38		Sodium chloride, 0.3-0.5%	Cilia beat all day, no cessation.
39		Sodium chloride, 0.5%, or blood serum in gas chamber, + CO_2	Initial cessation of ciliary movement, followed by vigorous activity; cilia beat longer in dilute solutions of CO_2.
40	Frog, esophageal mucosa (in situ)	Benzedrine, 0.1%	46 to 52% depression of ciliary movement.
41		Ephedrine HCl, 0.1%	25 to 32% depression of ciliary movement.
42		m-Synephrine HCl, 0.1%	17 to 25% depression of ciliary movement.
43	Frog, esophagus (in vitro)	Alcohol	Slight depression of ciliary activity.
44		Chloroform	Depressed ciliary activity.
45		Ethylene	Initial stimulation of ciliary activity.
46		Nitrous oxide	No effect on ciliary activity.
47		Sodium amytal	Depressed ciliary activity.
48		Sodium veronal	Depressed ciliary activity.
49	Frog, pharynx	Acetylcholine, 0.001%	No stimulation to moderate stimulation of ciliary activity.
50		Arecaline, 0.01%	Strong stimulation of ciliary movement.
51		Atropine, 0.001%	No effect on ciliary activity.
52		Caffeine, 2%	Ciliary movement accelerated for 3 minutes, ceased in 6 minutes.
53		Chloral hydrate, 0.5%	Cessation of ciliary movement in 5 minutes.
54		Chloretone, 0.1%	Cessation of ciliary movement in 5 minutes.
55		Choline, 1%	Slight stimulation of ciliary activity.
56		Epinephrine, 0.001%	Slight stimulation of ciliary activity.
57		Ether, 7.3%	Cessation of ciliary movement in 5 minutes
58		Physostigmine, 0.01%	No effect to strong stimulation of ciliary activity.
59		Pilocarpine, 0.01%[2]	Strong stimulation of ciliary activity.
60		Strychnine sulfate, 1%	Ciliary movement ceased in 10 minutes.
61		Veratrine sulfate, 1-1.5%	Metachronal activity[1] continues until cilia become quiet.
62	Frog, pharynx tissue culture	Cresols, o-, m-, and p-	m-Cresol accelerated, o- and p- retarded, ciliary activity.
63		Phenol, cresol, thymol	Toxic effect on ciliary activity decreases in order listed.
64		α- and β- Naphthol	Toxic effect on ciliary activity decreases in order listed.
65		Zootoxin, (Tyria spp); cantharidin crystal	Slight irritation; finally a decrease in ciliary activity, with separation of individual cells, cilia still beating.
66		Zootoxin, fish (Synancea verrucosa), diluted	Acceleration of ciliary movement followed by gradual reduction.
67		Zootoxin, toad dermal glands, 1:10,000 dilution	Intense acceleration of ciliary activity, followed by depression.
68	Cat, upper bronchi and trachea	Morphine, 0.125 mg/kg, and codeine, 0.75 mg/kg	Apparently little or no effect on ciliary movement.
69	Ox, tracheal tissue (excised)	Acetylcholine chloride, veratrine SO_4, caffeine, pilocarpine HCl, strophanthin	Accelerating effect decreases in order listed.
70		Barium chloride, chloral, cocaine HCl, quinine HCl, saponin	Retard ciliary movement.

/1/ Metachronal activity: characteristic ciliary beating of any ciliated cell or tissue in one direction in a regular sequence. /2/ Pilocarpine, 1.5% caused ciliary movement to cease in 6 minutes.

Part I: CHEMICAL (Concluded)

Cilia cease beating when underlying muscle contracts, resume beating when muscle relaxes.

	Ciliated Material	Chemical Factors	Results
		Vertebrates (concluded)	
71	Man, dog, guinea pig: mucous membrane strips, upper	Cocaine, 10-20%	Ciliary activity slowed; good recovery (5% cocaine does not decrease, may even increase, ciliary activity).
72	respiratory tract (man and dog	Ephedrine HCl, 3%	Not harmful, may increase activity.
73	tissue strips in chamber,	Epinephrine HCl, 0.1%	Definitely detrimental, slowing to stoppage.
74	guinea pig tissues in situ)	Eucalyptol, 1%	Depresses or stops ciliary activity, with fair or no recovery (0.5% no harmful effect).
75		Menthol, 0.5%	Mildly depresses ciliary activity (1% more depressing than 0.5%).
76		Mercurochrome, 2%	Definitely detrimental, slowing to stoppage of ciliary activity.
77		Silver nitrate, 0.5%	Immediately detrimental to ciliary activity; no recovery.
78		Silver proteinate, 5, 10, and 20%	Initial acceleration of ciliary activity, then retardation.
79		Thymol, 0.5-1%	Detrimental to ciliary activity, or cessation, with fair or no recovery.
80		Zinc sulfate, 2%	Definitely detrimental, slowing to stoppage.
81	Man, nose (extirpated mucous	Chlorbutanol	Slows, stops cilia; recovery from weak solutions.
82	membrane)	Penicillin (5000 units/ml normal saline) applied directly	Non-irritating to cilia.
83		Tuamine sulfate, 1%	No slowing of cilia during 41 minutes of observation.
84		Turamine sulfate, 1%	Average slowing time 97 minutes; recovery from weaker solutions.
85		Sulfadiazine, 2%, in triethanolamine and butoben	Ciliary movement stops, recovers when washed; effect caused by solvent (?).
86		Sulfadiazine, sulfanilamide, sulfathiazole, as powders	No effect on ciliary movement.
87		Sulfanilamide, in saline	No permanent deleterious effect.
88		Sulfathiazole, sodium, 5% (isotonic solution)	In 50% of tests cilia did not recover after immersion; caused by pH (10.17) (?).

Part II: PHYSICAL

	Ciliated Material	Physical Factors		Results
1	Paramecium	Electricity:	Direct current, 0.1-0.15 mA in water.	Animal stopped with anterior end toward the positive pole.
2	Beroe spp (Ctenophora), swimming plate		2 mA/ml passed longitudinally, at <20°C.	Inhibition effect, from cathode.
3	Turtle trachea		A C electrodes on trachea.	No change in ciliary frequency.
4	Paramecium	Hydrostatic	1-300 atmospheres.	No effect on ciliary rate.
5		pressure:	400-600 atmospheres.	Ciliary action ceased.
6	Mytilus (Mollusca), lateral cilia of gill		Gill in pressure bomb; pressures up to 1000 or 3000 lb/sq in.; (stroboscopic measurement),	Ciliary rates increase immediately, 7-20%; gradual return to normal.
7			Incr. in successive equal steps of pressure.	Increase in ciliary movement constant.
8			Pressure 5000 lb/sq in.	Basic ciliary frequency falls rapidly.
9			Pressure 6000 lb/sq in.	Irreversible damage.
10			Sudden decrease from 5000 or 1000 to 0 lb/sq in.	Immed. decrease of 3-25% in ciliary movement, with gradual return to normal.
11	Frog, pharynx tissue culture		From -7 to +7 atmospheres.	Little or no effect on ciliary rate.
12			-8 atmospheres.	Slight decrease in rate.
13	Frog, pharynx tissue culture	Light:	300-400 mμ (UV), short exposure.	Intense acceleration of ciliary movement.
14			500-620 mμ.	No effect.
15			650-722 mμ.	Temporary acceleration of ciliary movement.
16	pharynx in toto on slide		Darkness.	Cilia come to rest after about 45 minutes.
17			Light; after cilia come to rest in darkness.	Activity resumed in about 2 minutes.
18	Frog, pharynx in toto on slide	Mechanical	Floating cells.	Stimulation.
19	pharynx in situ	influences:	Base line; no substances.	Cilia inactive.
20			Ringer's solution.	Cilia active until fluid is removed.
21			Carbon particles.	Cilia active until particles are removed.
22			Camphor crystal.	Cilia active in front of crystal, inactive after its passage.
23	Paramecium bursaria	Radiation:	X-rays above 200,000 roentgens.	Decreased ciliary activity.
24			X-rays, 1,000,000 roentgens.	Ciliary activity decreased to very low level.
25	Frog, pharynx tissue culture		Radium bromide, 100 mg, 3 hr.	Temporary inhibition.
26	Toad (Bufo viridis), pharynx epithelium tissue culture		X-rays, 1-4 million roentgens.	Ciliary movement completely inhibited.
27	Oyster, Japanese (Ostrea	Osmotic	Sea water, dil. to 50% normal salinity.	Ciliary activity stimulated.
28	circumpicta)	effects:	Sea water, dil. from 50 to 20% normal salinity.	Ciliary activity declines to nearly zero.
29	Frog, buccal membrane, excised		Distilled water.	Initial strong stimulation of cilia; cells develop vesicles in 1 minute; ciliary movement ceases in 5 to 10 minutes.
30	Oyster (intact), feeding organs	Temper-	4-6°C	Decreased ciliary activity; normal feeding above this
31		ature:	25-30°C	range, almost none below. Optimum for ciliary activity; coordination of cilia decreases at temp below 15°C and above 25°C.
32	Modiolus (Mollusca) gill, lateral cilia		10-35°C	Ciliary vibration rate increases with temperature, from 3.5-15.8/second.
33	Frog, pharynx in toto on slide		20-27°C	Ciliary rate increases.
34			28°C	Ciliary rate increases notably.
35			35-38°C	Maximum increase in ciliary rate.
36			42°C	Cilia stop moving.
37	Rabbit, sinus in situ		7-12°C	Cilia stop moving.
38			18-33°C	Ciliary activity greatest (7 to 10 vibrations/second).
39			40°C	Movement of cilia greatly retarded.
40			43-44°C	Cilia stop moving; no recovery.

In this table ameboid movement means actual locomotion of the ameba by means of ectoplasmic contraction, protoplasmic streaming, or both. f = fresh water; s = sea water.

	Species[1]	Dimensions		Number of Nuclei[2]	Habitat	Average Rate of Movement[3]		Optimum (Highest Rate) Temp. ^{o}C
		Length μ	Width μ			μ/sec	^{o}C	
1	Trichamoeba, Pantin's "A"	120	50		s	1.9	22	20-24
2	Trichamoeba, Pantin's "B"	150	135		s	3.3	20	20-24
3	Trichamoeba, caerules	150	42	10-20	f	1.9	22	
4	T. clava	100	25		f	3.2	25	34-36
5	T. fusa	175	40		f	11.4	22	
6	T. gumia	100	41		s	2.0	22	
7	T. limax[4]				f	1.0		
8	T. oseosaccus	125	32		f	2.5	22	
9	T. pallida	60	12		s	2.0	27	
10	T. schaefferi	175	33		s	5.9	22	20-24
11	T. sphaerarum	25	6		s	1.1	27	
12	Pelomyxa clara	175	100	10-20	f	3.3	22	28.5-31
13	P. minima	78	35		f	0.55	23	34-36
14	P. palustris	580	200	300+	f	5.6	23	
15	P. scheidti	75	33	2^5 -	f	1.6	22	
16	Striolatus tardus	60	16	2^5	s	0.5	27	
17	Polychaos dubia	400	300		f	3.3	22	
18	Metachaos discoides[6]	450	45		f	2.5	26	34-36
19	M. fulvum[6]	70	24		s	2.5	27	
20	M. graniosa[6]	225	70		f	4.2	26	
21	M. gratum[6]	200	60		f	2.5	22	
22	M. oxyuris[6]	130	27		f	1.5	22	
23	M. rarum[6]	125	53		f	1.6	22	
24	Chaos chaos	1800	130	to 300	f	12.0	23	
25	Chaos nobilis	725	95	10-20	f	1.0	23	
26	Amoeba proteus pallas[7]	600	85		f	10.0	21	
27	A. proteus pallas[6, 7, 8				f	10.4	22	34-36
28	A. proteus pallas[6, 7				f	4.6[7]	23	
29	A. proteus[6, 9]	460	65		f	6.8	23	
30	Flabellula citata	20	37		s	2.0	25	
31	F. ciata				s	1.2	27	34-36
32	F. cresa	50	58		s	0.4	27	
33	F. mira	25	20		s	1.2	27	
34	F. mira				s	0.5[10]	23	
35	F. pellucida	30	80	10-20	s	0.9	27	
36	Mayorella augusta	250	74		f	1.7	22	
37	M. bigemma	200	110		f	2.6	25	
38	M. bulla	100	51		f	1.7	22	
39	M. copipes	45	23		s	0.8	25	34-36
40	M. conipes				s	2.0	27	
41	M. crystallus	30	22		s	0.5	27	
42	M. gemmifera	50	28		s	0.7	27	
43	Vexillifera aurea	80	31		s	0.8	27	
44	Astramoeba stella	40	18		f	0.4	22	
45	A. torrei	120	55		f	1.2	27	
46	Gibbodiscus gemma	35	30		s	0.6	27	
47	Flamella magnifica	50	50		s	0.8	27	
48	Dactylosphaerium acuum	60	60		s	0.3	27	
49	Pelomyxa lentissima	100	50	2^5	f	0.03	27	
50	Rugipes bilzi	70	34		f	1.7	23	
51	R. vivax	12	8		s	0.4	27	
52	Thecamoeba hilla	80	45		s	2.5	27	
53	T. rugosa	70	35		s	0.5	27	
54	T. verrucosa[11]	150	90		f	0.5	25	34-36
55	Hyaldiscus aureus	80	70		s	0.4	21	
56	H. elegans	40	40		s	1.3	21	
57	Cochlopodium clarum	40	39		s	0.3	21	
58	C. gulosum	80	55		s	0.4	21	

/1/ Grouped according to characteristic body shape during locomotion. General body shape: Lines 1-16, clavate; Lines 17-29, antler-shaped with large indeterminate pseudopods; Lines 30-49, 55-58, fan-shaped to triangular with small determinate pseudopods; Lines 50-54, oval without pseudopods. /2/ Unless otherwise indicated, the amebas listed have one nucleus, occasionally 2-4, except Flamella magnifica (Line 47) which has no formed nucleus. /3/ Rates at culturing temperatures during well-coordinated movement in clear culture fluid on glass surfaces, except Amoeba proteus pallas (Line 28), which was in 0.001 N NaCl after washing in distilled water. /4/ Original report in literature: Trichamoeba limax = Amoeba limax. /5/ Occasionally has only one nucleus. /6/ Rates determined while in clavate shape. /7/ Amoeba proteus pallas is North American name for Chaos diffluens. /8/ Mixture of Amoeba proteus pallas and Metachaos discoides. /9/ Chaos nitida is European name for Amoeba proteus. /10/ Mean rate. /11/ Original report in literature: Thecamoeba verrucosa = Amoeba verrucosa.

Protoplasmic streaming as considered in this table includes the shuttle-type flow of protoplasm in slime molds, cyclosis in higher plants, and streaming of protoplasm within rigid cell walls of algae. Streaming rates have been studied by use of many techniques, and results vary according to methods and conditions of measurement. Values were interpolated, where necessary, for comparison from graphic and tabular data in the literature. Parts I, II, and III show the effect of temperature on rate of streaming. Part I shows typical rates; Part II gives the temperature coefficient of Avena (oat) coleoptile. Part III reveals the effect of sudden changes of temperature, with estimates of temperature sensitivity. Because energy available for streaming has been associated with respiration, the effect of oxygen concentration is shown in Part IV. In Part V is presented the effect of various agents generally known specifically to affect respiration. Part VI demonstrates the effect of light on non-chlorophyll containing cells of Avena coleoptile observed in the orange-red phototropically inactive spectral region after exposure to various doses of blue light (4360 Å), at 23°C. Data show the fitness of the product rule (intensity x time), as well as the effect of total energy (dosage). Part IX shows the spectral sensitivity of this effect. The term "chemodinesis" (Part VII) is used to describe the action of certain alpha amino acids and other compounds which in very high dilution initiate protoplasmic streaming in leaf cells of Vallisneria. The lower concentration thresholds are presented in Part VIII. The action of various other agents on streaming is indicated in part VIII.

Part I: EFFECT OF TEMPERATURE

	Material (Investigator)	Rate of Streaming, μ/sec						
		5°C	10°C	15°C	20°C	25°C	30°C	35°C	40°C
1	Chara foetida (Velton, 1876)	20.4	26	38	42	52	76	93	72
2	Elodea canadensis (Velton, 1876)	4. 8	7. 7	8. 8	10. 5	11. 5	13. 3	16. 7	0
3	Vallisneria spiralis (Velton, 1876)	4. 7	8. 7	15. 1	20	26	31	38	
4	Nitella sp (Ganong, 1908)	10. 5	15. 3	20	27	34	43	47	37
5	Chara foetida (Lambers, 1926)	11. 2	24. 5	41	56	74	90		
6	Nitella mucronata (Lambers, 1926)	12. 7	28	41	60	75	96	109	
	Avena coleoptile (Bottelier, 1934)								
7	90 hr old	3. 4	4. 8	7. 0	8. 2	8. 3	8. 5		
8	200 hr old	3. 6	5. 7	7. 9	10. 4	12. 8	15. 8		

Part II: TEMPERATURE COEFFICIENT

	Temp, °C	Avena Coleoptile	
		Age: 90 hr Q_{10}	Age: 140-200 hr Q_{10}
1	5-10	1. 8-2. 1	1. 9-2. 2
2	10-15	1. 8	1. 8
3	15-20	1. 1	1. 8
4	20-25	1. 1	1. 7
5	25-30	0. 9	1. 5
6	30-35	0. 7	1. 1
7	35-40	0. 9	

Part III: EFFECT OF SUDDEN CHANGES OF TEMPERATURE

T_o = initial temperature; T = final temperature prevailing during the test; R_o = average streaming rate (μ/sec) at T_o

	Temp, °C		R_o	Rate of Streaming, μ/sec, at Specified Interval (min)											Sensitivity[1]
	T	T_o		10	20	30	40	50	60	70	80	90	100	110	120	
								Nitella flexilis								
1	24. 5	13. 8	28. 5		55	55	55	55	55	55	55	55	55	55	55	
2	31. 5	13. 8	28. 5		80	80	80	80	80	80	80	80	80	80	80	
3	37. 5	13. 8	28. 5		99	99	99	99	99	99	99	99	99	99	99	
4	12. 8	19	55		36	36	36	36	36	36	36	36	36	36	36	
5	12. 8	22	62. 5		36	36	36	36	36	36	36	36	36	36	36	$\frac{100}{12^2} = 8.3$
6	12. 8	24. 3	70		36	36	36	36	36	36	36	36	36	36	36	
7	12. 8	26	74		24	28	32	34	36	36	36	36	36	36	36	
8	20	25	86		71	71	71	71	71	71	71	71	71	71	71	
9	20	27. 5	93		64	68	69	70	71	71	71	71	71	71	71	$\frac{100}{6} = 16.6$
10	20	30	100		62	65	66	68	69	70	71	71	71	71	71	
11	20	35	114		45	50	52	54	56	58	60	62	63	64	65	
12	25	30	100		83	83	83	83	83	83	83	83	83	83	83	
13	25	32. 5	106		83	83	83	83	83	83	83	83	83	83	83	
14	25	33	106		83	83	83	83	83	83	83	83	83	83	83	$\frac{100}{9} = 11.1$
15	25	35	113		77	80	82	82	83	83	83	83	83	83	83	
16	25	38. 5	125		71	74	76	77	78	80	81	81	82	83	83	
17	25	40	131		25	40	48	54	58	62	65	68	70	71	72	
								Avena coleoptile								
18	13	21	12	6. 0	6. 2	6. 4	6. 6	6. 6	6. 6	6. 6	6. 6	6. 6	6. 6	6. 6	6. 6	
19	13	24	12. 8	0. 9	0. 1	2. 1	3. 2	4. 4	5. 1	5. 8	6. 3	6. 9	7. 5	7. 6	7. 6	$\frac{100}{7.5} = 13$
20	13	28	12. 6	12. 6	0	0. 4	1. 2	2. 6	4. 5	5. 8	6. 6	7. 3	7. 7	7. 7	7. 7	
21	21	25	11	4. 2	9. 1	9. 9	10. 2	10. 3	10. 3	10. 3	10. 3	10. 3	10. 3	10. 3	10. 3	
22	21	27	10	0	4. 5	9. 9	11. 9	12. 1	12. 1	12. 1	12. 1	12. 1	12. 1	12. 1	12. 1	$\frac{100}{3.3} = 30$
23	21	36	3. 4	0	0. 1	0. 1	0. 2	0. 1	0. 2	0. 1	0. 1	0. 2	0. 4	1. 4	3. 6	

/1/ Sensitivity = 100 ÷ maximum temp difference giving no rate lag.

Part IV: EFFECT OF OXYGEN

	Material	O_2 Conc. % Sat. (ml/L)	Streaming Rate	Per Cent of Normal Rate of: Streaming	Respiration		Material	O_2 Conc. % Sat. (ml/L)	Streaming Rate	Per Cent of Normal Rate of: Streaming	Respiration
1		21(6. 27)	Normal	100	100	12	260 hr old, 25°C	21(5. 85)	13. 4 μ/sec	100	
2	Physarum	2. 4(0. 72)	Reduced		60	13	260 hr old, 21°C	4(1. 23)	9. 0 μ/sec	88	
3	polycephalum,	1. 0(0. 30)	Reduced		30	14	260 hr old, 26°C	4(1. 02)	9. 1 μ/sec	68	
4	at 22°C	0. 3(0. 08)	Reduced		9			O_2 Conc.			
5		0. 1(0. 03)	Reduced		3			% Sat. (ml/L)			
6		0(0)	Reduced	0	0		Avena coleoptile				
	Avena coleoptile					15	80 hr old, 25°C	10. 8-14. 6[1](3. 1-4. 1)		100	100^2
7	96 hr old, 21°C	100(30. 4)	9. 9 μ/sec	99		16	80 hr old, 25°C	14. 6[1]-21(4. 1-5. 7)			50^2
8	96 hr old, 26°C	100(27. 8)	10. 1 μ/sec	132		17	95 hr old, 25°C	10. 8-18. 2[1](3. 1-5. 3)		100	100^2
9	96 hr old, 21°C	21(6. 25)	10. 0 μ/sec	100		18	95 hr old, 25°C	18. 8[1]-21(5. 3-5. 7)			50^2
10	96 hr old, 26°C	21(5. 85)	10. 1 μ/sec	100		19	130 hr old, 25°C	11, 6-12, 4[1](3. 2-3. 5)		100	100^2
11	260 hr old, 21°C	21(6. 32)	10. 2 μ/sec	100		20	130 hr old, 25°C	12[1]-21(3. 5-5. 7)			50^2

/1/ Critical O_2 tension. /2/ Rates uniform within indicated O_2 ranges, there being a sharp change in rate at the critical oxygen tension.

Part V: EFFECT OF CHEMICAL RESPIRATORY AGENTS

	Agent	Residual Respiration % Control	Effect on Streaming
	Physarum polycephalum[1]		
1	KCN, 1 x 10^{-4} M	77	
2	KCN, 5 x 10^{-4} M	47	
3	Air, control[2]	100	
4	Air + KCN, 1 x 10^{-3} M[2]	15.1	++++ (indefinitely).
5	2.4% O_2, control[2]	59	+++ (after 7 hr), ++++ (indefinitely).
6	2.4% O_2 + KCN, 1 x 10^{-3} M[2]	5.2	
7	After 2 hr in 2.4% O_2 and 3 hr in KCN[2]		+++
8	After 5 hr in KCN (2 hr of which in air)[2]		++
9	1.0% O_2, control[2]	30.5	
10	1.0% O_2 + KCN, 1 x 10^{-3} M[2]	1.4	
11	After 2 hr in 1.0% O_2 and 3 hr in KCN[2]		+++
12	After 7 hr in KCN (2 hr of which in air)[2]		+
13	DNP, 2 x 10^{-5} M	122-137	Stopped within 5 min (reversible).
14	DNP, 1.25 x 10^{-4} M	138-143	Stopped within 10 min (reversible).
15	Na iodacetate, 5 x 10^{-3} M	35	Not stopped until disintegration occurs.
16	NaN_3, 1 x 10^{-4} M	30	Stopped quickly (reversible).
17	Na pyrophosphate, 2(10^{-2} to 10^{-4} M)	No effect	No effect.
	Avena coleoptile		
18	KCN, 3 x 10^{-4} M	54-67	53%[3] (reversible).
19	KCN, 1 x 10^{-2} M		53-61%[3] (reversible).
20	KCN, 1 x 10^{-1} M		Stopped within 22 min (irreversible).
21	DNP, 5 x 10^{-6} M		100%[3].
22	DNP, 1 x 10^{-5} M	100^4	
23	DNP, 2.5 x 10^{-4} M	37^4	52%[3].
24	DNP, 5 x 10^{-4} M	3^4	Stopped within 22 min (irreversible).
	Nicotiana tabacum[5]		
25	KCN, 8 x 10^{-5} to 2 x 10^{-3} M	40-50	40%[3].

/1/ Streaming measurements not absolute because of irregular change of rate and direction of movement. Relative rates presented as number of plus signs. /2/ Data applicable to same plasmodium. /3/ Per cent of control. /4/ Rates sustained 30 minutes after rinsing. /5/ Data applicable to marginal cells of leaf.

Part VI: EFFECT OF VARIOUS DOSES OF LIGHT (4360 Å) ON AVENA COLEOPTILE

	Dosage[1] ergs/sq cm	Illumination Intensity ergs/sq cm/sec	Illumination Time sec	Reaction[2]		Dosage[1] ergs/sq cm	Illumination Intensity ergs/sq cm/sec	Illumination Time sec	Reaction[2]		Dosage[1] ergs/sq cm	Illumination Intensity ergs/sq cm/sec	Illumination Time sec	Reaction[2]
1	10	2	5	-29	14	110	11	10	-118	26	440	11	40	-84
2	12	23.6	0.5	-54	15	118	23.6	5	-92	27	472	23.6	20	-54
3	20	2	10	-69	16	120	2	60	-112	28	480	2	240	-107
4	20	5	4	-67	17	142	23.6	6	-97	29	600	5	120	-69
5	22	11	2	-74	18	160	5	32	-103	30	660	11	60	-22
6	24	23.6	1	-75	19	180	2	90	-160	31	746	23.6	32	-15
7	40	2	20	-72	20	189	23.6	8	-136	32	944	23.6	40	+32
8	47	23.6	2	-87	21	220	11	20	-169	33	1320	11	120	+132
9	55	11	5	-70	22	236	23.6	10	-105	34	1420	23.6	60	+42
10	66	11	6	-74	23	240	2	120	-118	35	2100	23.6	90	+28
11	80	2	40	-91	24	360	2	180	-104	36	2800	23.6	120	+26
12	88	11	8	-78	25	378	23.6	16	-81	37	4200	23.6	180	+4
13	94	23.6	4	-77										

/1/ Energy (intensity x time). /2/ Algebraic sum (average of 1-20 separate experiments for each energy value) of per cent departures from normal rate. Negative values indicate a decrease in streaming; positive values, an increase.

Part VII: CHEMODINESIS: VALLISNERIA

	Compound	Molarity	Threshold %		Compound	Molarity	Threshold %		Compound	Molarity	Threshold %
1	L-Histidine	5 x 10^{-8}	7.7 x10^{-7}	5	Benzoic acid	1 x 10^{-5}	1 x 10^{-4}	8	Histamine	8 x 10^{-5}	4 x 10^{-4}
2	L-Asparagine	1.5 x 10^{-6}	2 x 10^{-5}	6	Cinnamic acid	1 x 10^{-5}	1 x 10^{-4}	9	Na-β-indole acetate	1 x 10^{-4}	1.9 x 10^{-3}
3	L-Alanine	1 x 10^{-6}	8.9 x 10^{-6}	7	Salicylic acid	1 x 10^{-5}	1 x 10^{-4}	10	Leaf extract (Vallisneria)		2.5 x 10^{-5}
4	D-Galacturonic acid	5 x 10^{-6}	1 x 10^{-4}								

Part VIII: EFFECT OF CERTAIN PHYSICAL AND CHEMICAL AGENTS

	Agent	Material	Effect on Streaming		Agent	Material	Effect on Streaming
1	Ethyl chloride, 25%	Physarum	Stops in 10-15 sec.	15	3-Indolenacetic acid, 0.005-0.5 mg/L	Avena	Increases up to 119%[1].
2	Ethyl chloride, 18%	Physarum	Stops in 20 sec.				
3	Ethyl chloride, 5%	Physarum	No effect.	16	Heavy metals, 5 x 10^{-6} to 5 x 10^{-2} M	Physarum	Decreases: Ag>Hg> Cd>Tl>Cu>Pb>Zn> Y>Sr>La>Rb.
4	$LiCl_3$, 0.1 M	Chara	Stops in 5 hr.				
5	$CaCl_2$, $BaCl_2$, 0.1 M	Chara	Stops in 6 hr.				
6	Ethyl ether, low conc.	Physarum	Accelerates.				
7	Ethyl ether, high conc.	Physarum	Inhibits.	17	pH 3-8	Chara	Max. at pH 5.5 & 7.
8	Ethyl ether, 10-32 mg/L	Avena	Inhibits.	18	pH 5-7	Hordium[2]	Max. at pH 5.8 & 6.4.
9	Sodium chlorate	Elodea	Inhibits.	19	Hydrostatic pressure, 400 atmos.	Nitella	Stops(reversible).
10	Menotonin extract	Elodea, Nitella	Stops.	20	Hydrostatic pressure, 600 atmos.	Elodea	-50%(reversible).
11	Quinine hydrochloride, 1:150	Physarum	Accelerates, then stops.	21	X-radiation, 25-70, 000 r.	Tradescantia	Inhibits.
12	Morphine, 1:20	Physarum	Stops in 2-3 min.	22	Electric current, 3.1 x 10^{-8} amps.	Chara, Nitella	Stops temporarily.
13	Colchicine, 1:1000	Elodea	Accelerates.				
14	Ethylene chlorhydrin, 0.025-0.075 M	Elodea, Nitella	Accelerates.	23	Electric current, 1 to 5 x 10^{-6} amps.	Avena	Inhibits, stops temporarily.

/1/ No effect has been reported at concentration of 0.01-10 mg/L. /2/ Observation from cells of root hairs.

Part IX: EFFECT OF VARIOUS WAVE LENGTHS: AVENA COLEOPTILE

	Wave Length Å	Dosage[1]	Reaction[2]	Equivalent Energy[3]	Sensitivity		Wave Length Å	Dosage[1]	Reaction[2]	Equivalent Energy[3]	Sensitivity
1	3660	270	-46	16	6	6	4360		Cf Part VI		100
2		760	-85	90	12	7		230	-16	7	3
3		21	-15	7	33	8	5460	240	-15	7	3
4	4550	67	-33	13	20	9		1790	-60	30	1.7
5		190	-90	95	50	10	5780	9000	+1		<1
						11	6200	Cf Fn 4	+1		<1

/1/ Intensity x time. /2/ Algebraic average of per cent departures from normal rate. Negative values indicate a decrease in streaming; positive values, an increase. /3/ Equivalent energy required at 4360 Å for comparable effect. /4/ Approximately 70 ergs/sq cm/sec.

300. TRANSPIRATION RATES

Factors influencing transpiration include solar radiation, humidity, temperature, and wind. Part I (Section 1) presents the rate of water loss as influenced by these conditions. Certain soil factors indicated in Part I (Section 2) are involved in water absorption, giving a corresponding effect on transpiration. Part II gives hourly and day and night variations of corn (Zea mays). Values are averages for 30 days during July and August, Nebr. Agr. Exp. Sta. Part III reveals diurnal transpiration of mullein (Verbascum thapsus). Part IV gives the total water loss during the growing season. Part V denotes the water required to produce one gram of dry matter, the transpiration ratio.

Part I: TRANSPIRATION RATES: VARIOUS CONDITIONS

Section 1.

	Species	Temp °C	Light	RH[1] %	Water Loss g/sq dm/hr
	Herbaceous Plants				
1	Corn (Zea mays)		12-2 PM		5
2	Sorghum, kafir (Sorghum vulgare)		12-2 PM		2.2
3	Sorghum, milo (S. vulgare)		12-2 PM		4.3
4	Sunflower (Helianthus annuus)	27		22[3]	0.7;0.9
5		38		22[3]	1.2;2.8
6		49		22[3]	2.1;4.9
7	Tobacco (Nicotiana tabacum)	23-26		68	1.5
8		37-38		68	3.6
	Woody Plants				
9	Box elder (Acer negundo)	38	Shade	32	0.6
10	Buckeye (Aesculus glabra) Germander (Teucrium scorodonia)	38	Shade	32	0.7
11	Sun leaves	26-30	Sun	38-46	0.7
12	Shade leaves	26-30	Sun	38-46	0.4
13	Sun leaves	18-19	Shade	75-76	0.3
14	Shade leaves	18-19	Shade	75-76	0.1
15	Maple (Acer saccharinum)	13-17		58-78	1.0
16	Oak (Quercus rubra)	38	Shade	32	0.8
17	Orange (Citrus sinensis)	21-38		40-98	0.2
18	Peach (Prunus persica)	21-38		40-98	0.7
19	Pecan (Carya illionensis)	24	Day	45-60	1.07
20		20-23	Night	61-65	0.09
21	Pine (Pinus ponderosa)	13-17		58-78	0.2
22	Pineapple (Ananas comosus)	31		59	2.0
23		24		85	0.03
24	Spruce (Picea engelmannii)	13-17		58-78	0.2
25	Sycamore (Platanus occidentalis)	38	Shade	32	0.8
26	Walnut (Juglans nigra)	25	Day	45-60	0.09
27		68-73	Night	61-65	0.08

/1/ Relative humidity. /2/ g per sq dm leaf surface per hr. /3/ Wind, 6 mi/hr.

Section 2.

	Species	Specified Condition	Water Loss mg/sq cm/hr[1]
1	Apple (Pyrus malus)	Straw mulch	17.2
2		Without mulch	14.3
3	Cotton (Gossypium herbaceum)	Soil of low salt conc.	15
4		With 0.8% Ca $(NO_3)_2$	1.6
5	Euphorbia (Euphorbia capitellata)	10 AM - 2 PM Evaporation 0.01 g/sq cm^2	4.5
6		10 PM - 7 AM Evaporation 0.01 g/sq cm^2	0.1
7	Grapefruit (Citrus grandis)	Soil temp 27°C	4.6
8		Soil temp 35°C	3.1
9	Houseleek (Sempervium howorthii)	Wind velocity 1100 cm/sec	0.6
10		Wind velocity 570 cm/sec	0.2
11	Pepper (Capsicum annuum)	Soil moisture 50%[3]	3.5
12		Soil moisture 25%[3]	1.1
13	Wheat (Triticum aestivum)	Good loam soil	2.1
14		Poor soil	1.1

/1/ Mg per sq cm leaf surface per hr. /2/ Evaporation from free water surface. /2/ Per cent water holding capacity of soil.

Part II: TRANSPIRATION RATES; CORN: DIURNAL VARIATION

	Period	Temp °C	RH[1] %	Wind mi/hr	Water Loss Per Plant[2] g	Evaporation[3] g
1	8 AM	23.1	80	6	84	4.8
2	9	25.5	73	7	111	7.7
3	10	27.6	67	8	167	11.6
4	11	29.3	63	8	215	15.0
5	12	30.8	58	9	279	19.2
6	1 PM	31.9	55	9	329	23.7
7	2	32.7	53	9	356	24.5
8	3	32.9	52	9	354	23.8
9	4	32.8	50	9	343	22.2
10	5	32.2	51	8	294	18.5
11	6	31.2	53	8	217	14.1
12	7	28.4	58	7	132	10.2
13	8	27.6	64	7	64	6.4
14	Av. for day	29.8	59.8	8	226	15.5
15	Av. for night	22.7	81.5	6	16	2.3

/1/ Mean relative humidity. /2/ Water transpired from one plant. /3/ Water evaporated from 36 sq in. free-water surface, under identical conditions.

Part III: TRANSPIRATION RATES, MULLEIN; DIURNAL VARIATION

	Period	Temp °C	Diffusion Pressure Deficit mm Hg	Sunlight %	Water Loss g/sq dm/hr[1]
1	1:00 AM	18.3	6.40		0.09
2	2:00	17.8	6.21		0.09
3	3:00	17.2	5.98		0.09
4	4:00	16.7	5.79		0.09
5	5:00	16.1	5.57		0.09
6	6:00	15.7	5.30	0	0.16
7	7:00	15.7	5.30	70	0.33
8	8:00	16.7	5.54	100	0.53
9	9:00	21.1	8.37	100	1.33
10	10:00	26.7	15.61	100	2.48
11	11:00	29.4	22.83	100	2.68
12	12:00	32.2	27.51	100	3.06
13	1:00 PM	33.9	31.48	100	2.80
14	2:00	35.0	34.26	100	2.42
15	3:00	33.9	31.48	100	1.65
16	4:00	32.2	28.22	10	1.60
17	5:00	29.4	22.83	0	0.68
18	6:00	25.6	14.63		0.13
19	7:00	23.3	9.56		0.13
20	8:00	22.2	7.55		0.13
21	9:00	22.2	7.35		0.13
22	10:00	21.7	7.13		0.13
23	11:00	21.1	6.88		0.13
24	12:00	21.1	6.88		0.13

/1/ g per sq dm leaf surface per hr.

Part IV: TRANSPIRATION RATES: GROWING SEASON

	Species	Length of Season; Location	Water Loss L
1	Apple (Pyrus malus)	188 da; New York	8,200
2	Coconut (Cocus nucifera)	365 da; Philippines	19,000
3	Corn (Zea mays)	May 5-Sept 8; Kansas	245
4	Cowpea (Vigna sinensis)	May 19-Sept 2; Kansas	60
5	Date (Phoenix dactylifera)	365 da; Sahara Desert oasis	160,000
6	Potato (Solanum tuberosum)	Apr 18-July 30; Kansas	115
7	Ragweed (Ambrosia sp)	June 1-Aug 30	640
8	Sunflower (Helianthus annuus)	May 26-Aug 23; Kansas	560
9	Tomato (Lycopersicon esculentum)	May 19-Sept 2; Kansas	115
10	Wheat, winter (Triticum aestivum)	Oct 15-June 28; Kansas	115

Part V: TRANSPIRATION RATIO: SEASONAL VARIATION

	Species	Seasonal Water Requirement						
		1912	1913	1914	1915	1916	1917	Av
	Colorado							
1	Alfalfa (Medicago sativa)	557	834	890	695	1047	822	824
2	Amaranth (Amaranthus retroflexus)		320	306	229	340	307	300
3	Barley (Hordeum vulgare)	443		501	404	664	522	507
4	Corn (Zea mays)	280	399	368	253	495	346	357
5	Cotton (Gossypium hirsutum)	488	657	574	443	612	522	549
6	Cowpea (Vigna sinensis)		571	659	413	767	481	578
7	Grama-grass (Bouteloua gracilis)			389	312	536	290	332
8	Oat (Avena sativa)	449	617	615	445	809	636	595
9	Rye (Secale cereale)			622	469	800	625	629
10	Setaria (Setaria italica)	187	286	295	202	367	284	273
11	Sorghum (Sorghum vulgare sudan.)			394	260	426	378	365
12	Wheat, durum (Triticum aestivum)	394	496	518	405	636	471	487
	South Dakota							
13	Alfalfa (Medicago sativa)	735	735	1038	696	973	866	790
14	Setaria (Setaria italica)	239	293	311	171	233	278	254
15	Sorghum (Sorghum vulgare sudan.)				272	314	344	310
16	Wheat, durum (Triticum aestivum)	463	436	528	333	352	487	433

301. ION ABSORPTION AND ACCUMULATION: PLANTS

Parts I and II indicate the differential absorption among cations present in the culture solution. The accumulation ratio (internal: external), shown in Parts I and III, is the ratio of concentration in cell sap to that in the external medium. Ratios greater than 1 indicate the movement of ions against a concentration gradient, i.e., from a region of lesser concentration to a region of greater concentration for each ion that accumulates. Part III reveals the influence of temperature on absorption by excised barley roots (Hordeum vulgare). Values were determined at end of 10 hours. Part IV shows the factors of time and distance from apex of excised barley roots on Rb absorption. Roots were placed in 0.005 M RbBr during the specific periods. Part V presents the course of ion absorption from 0.001 M $MnCl_2$ by root discs of beet (Beta vulgaris) as influenced by pretreatments. The root discs were washed at 25°C for 24 hr in distilled water (through which moist N_2, O_2, or air was passed) prior to transferring in the $MnCl_2$ solution. Because data have been greatly condensed, values should be considered with caution.

Part I: ION ABSORPTION AND ACCUMULATION: ALGAE

Ion	Chara ceratophylla			Nitella clavata			Valonia macrophyza		
	Ion Concentration		Accumulation Ratio	Ion Concentration		Accumulation Ratio	Ion Concentration		Accumulation Ratio
	Cell Sap	Brackish Water		Cell Sap	Pond Water		Cell Sap	Sea Water	
	mole x 10^{-3}			mole x 10^{-3}			mole x 10^{-3}		
1 Ca	5.3	1.8	2.9	10.2	0.8	12.8	1.7	12	0.1
2 Mg	15.5	6.5	2.4	17.7	1.7	10.4	Trace	57	
3 Na	140	60	2.3	10.0	0.2	50	90	500	0.2
4 K	88	1.4	63	54	0.05	1080	500	12	42
5 Cl	225	73	3.1	91	0.9	100	600	520	0.9
6 SO_4	3.9	2.8	1.4	8.3	0.3	28	Trace	36	

Part II: ION ABSORPTION AND ACCUMULATION: HIGHER PLANTS

Species	Cations Absorbed							Species	Cation Absorbed					
	Na	K	Mg	Ca	Sr	Total			Na	K	Mg	Ca	Sr	Total
	Equivalent Percentages					mEq/kg dry wt			Equivalent Percentages					mEq/kg dry wt
1 Buckwheat (Fagopyrum esculentum)	0.9	39	27	33	0.011	3230		8 Saltbush (Atriplex litoralе)	10.7	56	23	10	0.006	4340
2 Corn (Zea mays)	2.9	70	16	11	0.005	2420		9 Spinach (Spinacia oleracea)	4.5	52	31	13	0.006	6520
3 Oat (Avena sativa)	3.7	73	14	9	0.004	2040		10 Sunflower (Helianthus annuus)	2.3	54	17	27	0.008	3020
4 Pea (Pisum sativum)	6.0	62	12	20	0.008	2140		11 Tobacco (Nicotiana tabacum)	4.0	51	24	21	0.006	4440
5 Plantain (Plantago lanceolata)[2]	12.2	45	18	24	0.010	3690		12 Tomato (Lycopersicon esculentum)[2]	4.1	44	25	27	0.010	4290
6 Plantain (P. maritima)[2]	28	39	11	21		4370		13 Vetch (Vicia sativa)	10.6	44	19	26	0.011	2470
7 Saltbush (Atriplex hortensia)	19.7	39	31	10	0.004	4790		14 Culture solution	25	25	25	25	0.006	

/1/ The sum of equivalents of all fixed cations in 1 kg dry wt of plant tissue (cf Total) was determined and the amount of each cation expressed as percentage of this total. Analyses of entire plants (shoot and root), except as otherwise specified. /2/ Analyses of shoots.

Part III: EFFECT OF TEMPERATURE: BARLEY ROOTS

Temp °C	Ion Concentration						Accumulation Ratio		
	Culture Solution			Expressed Sap					
	K	NO_3	Br	K	NO_3	Br	K	NO_3	Br
	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L			
1 6	9.62	8.35	4.84	34.7	4.8	5.9	3.6	0.6	1.2
2 12	9.32	8.27	4.76	47.7	11.1	8.8	5.1	1.3	1.9
3 18	8.45	7.75	4.64	73.2	23.7	14.6	8.7	3.1	3.1
4 24	7.98	7.29	4.30	97.8	38.1	30.9	12.3	5.2	7.2
5 30	7.42	6.70	3.94	112	47.8	39.9	15.1	7.1	10.1

Part IV: EFFECT OF TIME AND DISTANCE: EXCISED BARLEY ROOTS

Values are mEq/kg fresh weight.

Distance from Apex cm	Root Weight[1] mg	Rubidium Absorbed		Per Cent Gain 25-50 hr
		End of 25 hr mEq/kg	End of 50 hr mEq/kg	
1 to 1	33	32	44	38
2 1-2	38	26	34	29
3 2-3	39	25	27	8
4 3-4	38	24	26	8
5 4-5	40	24	25	6

/1/ Weight of 30 roots.

Part V: EFFECT OF PRETREATMENT: BEET ROOT DISCS

Values for manganese are followed, in parentheses, by those for chloride. Negative values indicate loss from the tissue to the bathing solution.

Observation Period hr	Percentage Absorption of Mn and Cl			
	Untreated	Pretreatment		
		Nitrogen	Oxygen	Air
1 5	18.3(-2.0)	18.7(-0.2)	21.9(5.3)	19.1(2.3)
2 48	21.3(1.5)	27.9(14.2)	40.7(35.4)	32.9(27.3)

Observation Period hr	Percentage Absorption of Mn and Cl			
	Untreated	Pretreatment		
		Nitrogen	Oxygen	Air
3 120	58.5(51.8)	76.2(60.1)	78.4(72.6)	79.5(74.6)
4 192	77.4(73.2)	84.3(79.1)	100(83.8)	100

302. TRANSLOCATION RATES: PLANTS

Values are linear rates of movement in phloem.

Substance	Species	Translocation Rate cm/hr	Method of Determination
Virus			
1 Curly top	Sugar beet (Beta vulgaris)	150	
2 Curly top, Argentine	Sugar beet (B. vulgaris)	7.5	Infectivity of tissue
3 Curly top	Dodder (Cuscuta sp), scropetal	10	
4 Curly top	Dodder (Cuscuta sp), basipetal	0	
5 Curly top	Tobacco (Nicotiana tabacum)	1.2	
6 Mosaic	Tobacco (N. tabacum)	17.8	
7 Streak	Corn (Zea mays)	20[1]	
8 9 Fluorescein 10	Various species	2-50	Observation of movement
	Bryonia sp	50(15-65)	
	Geranium (Pelargonium zonale)	20-35	

Substance	Species	Translocation Rate cm/hr	Method of Determination
11 Sugars	Oak (Quercus robor)	130-400	Conc. change
12 Assimilates[2]	Pumpkin, squash (Cucurbita spp)	55-160	Dry wt gain
13 Sucrose	Bean (Phaseolus vulgaris)	84	C^{14} tracer
14 Sucrose	Soybean (Glycine soja)	84	C^{14} tracer
15 Indoleacetic acid	Cucumber (Cucumis sativus)	18.5	Auxin assay
16	Oat (Avena sativa)	1.0-1.2	
17	Squash (Cucurbita sp)	20	
18 2, 4-D	Alligator weed (Alternanthera sp)	4.2	Bending of stem
19	Bean (Phaseolus vulgaris)	10-100	
20 Iron	Bean (P. vulgaris)	>43	Fe^{55} tracer
21 Phosphate		60(45-90)	P^{32} tracer
22 Sulfate		>41	S^{35} tracer

/1/ Minimum rate. /2/ Unspecified carbohydrates.

303. OSMOTIC RELATIONS: PLANT CELLS

Osmotic pressure (O.P.), a direct function of cell sap concentration, effects movement of water into roots and throughout the plant. Diffusion pressure gradients influencing translocation of solutes appear to arise primarily from osmotic differences between adjacent supplying and receiving cells. Diffusion pressure deficit (D.P.D.) = O.P.-T.P. (turgor pressure). Part I presents variation in leaves. Part II shows effect of specified factors. Part III gives seasonal values of shoots, plants grouped by depth of rooting. Part IV reveals changes with age of seedling, wheat (Triticum aestivum). Part V indicates values for tissues and organs. Parts VI and VII present diurnal and seasonal variations. Part VIII shows effect of soil water and soil nutrient contents on corn (Zea mays). Part IX specifies habitats, and Part X presents plant-group values. Values are atmospheres.

Part I: LEAVES VS O. P.

	Species	O. P.		Species	O. P.
	Herbaceous Plants			Trees	
1	Bedstraw (Galium sparine)	9.6	18	Ash (Fraxinus americana)	16.4
2	Beet (Beta vulgaris)	14	19	Birch (Betula lutea)	12.6-16.0
3	Bluegrass (Poa pratensis)	12.6-18.6	20	Cottonwood (Populus deltoides)	21.3
4	Burdock (Arctium minus)	9.8-13.7	21	Dogwood (Cornus florida)	11.1-16.7
5	Cattail (Typha latifolia)	9.7-11.8	22	Lemon (Citrus limonia)	15.1-21.4
6	Cinnamon fern (Osmunda cinnamomea)	9.8	23	Locust (Robinia pseudoacacia)	9.8-14.3
7	Cocklebur (Xanthium sp)	8.4-10.7	24	Maple (Acer rubrum)	11.2-16.7
8	Cotton (Gossypium sp)	22	25	Oak (Quercus alba)	15.8-18.4
9	Dandelion (Taraxacum officinale)	8.5-10.8	26	Oak (Q. coccinea)	19.1
10	Goldenrod (Solidago sp)	10.3	27	Pine (Pinus spp)	16.0-18.4
11	Iris (Iris germanica)	13.1	28	Poplar (Populus alba)	19.7-20.1
12	Lamb's-quarters (Chenopodium album)	13.2	29	Spruce (Picea engelmannii)	11.5-23.5
13	Mullein (Verbascum thapsus)	8.0-10.1	30	Sweetgum (Liquidambar styraciflua)	13.3-15.5
14	Pea (Pisum sativum)	9.2	31	Sycamore (Platanus occidentalis)	13.5
15	Pokeweed (Phytolacca decandra)	8.5-9.5	32	Walnut (Juglans nigra)	12.6-18.3
16	Sunflower (Helianthus annuus)	13.8-18.0	33	Willow (Salix alba)	12.3-14.2
17	Touch-me-not (Impatiens biflora)	4.6-8.4	34	Yellow-poplar (Liriodendron tulipifera)	11.3-16.4

Part II: FACTORS VS D.P.D., O.P.

	Factors	D.P.D.	O.P.
	Temperature		
1	0°C	0.7	14.3
2	13°C	2.0	13.5
3	23°C	3.3	12.7
4	30°C	4.0	11.1
	Height on tree		
5	16 m		18.3
6	13 m	10.5	18.3
7	12 m	9.9	17.2
8	10 m	9.3	18.2
9	6 m		17.8
10	2 m	7.5	16.8
	Distance from growing point (root)		
11	1.5 mm	7.4	11.3
12	3.0 mm	7.7	11.7
13	5.0 mm	10.0	12.7
14	8.0 mm	9.4	9.8

Part III: SHOOTS VS O. P.

	Species	Osmotic Pressure Apr 19	Apr 24	May 8	May 28	Jun 8	Jun 20	Jul 2	Jul 9	Jul 31
	Shallow-rooted Plants									
1	June grass (Koeleria cristata)	16.4	17.4	24.1	35					
2	Lomatium (Lomatium foeniculaceum)	11.5	14.6	16.1	20.2					
3	Milk vetch (Astragalus crassicarpus)	10.9	13.2	15.4	18.7					
	Relatively Deep-rooted Plants									
4	Bluestem (Andropogon scoparius)	8.1	9.6	9.9	25.3	18.1	17.4	31.3		
5	Goldenrod (Solidago glaberrima)		12.0		12.8	14.3	16.8			
6	Sunflower (Helianthus rigidus)			12.6	19.9	15.2	22.9	36.9		
	Deep-rooted Plants									
7	False-indigo (Baptisia leucophaea)	8.6	10.8	12.0	14.8	16.0	16.7	17.3		
8	Lead plant (Amorpha canescens)		11.6	13.1	20.6	16.2	15.1	17.2	20	22.1
9	Scurf pea (Psoralea tenuiflora)		12.2	14.2	17.8	16.0	16.8	15.2	17.2	15.8

Part IV: WHEAT SEEDLING: AGE VS O. P.

	Age	Entire Plant	Shoot	Root
1	2 da	10.7		
2	3 da	9.8		
3	4 da	8.0		
4	5 da	7.8		
5	6 da	7.1		
6	7 da	6.6		
7	8 da	6.0		
8	9 da	5.4		
9	10 da	5.1	6.06	3.06
10	13 da	4.9		
11	15 da	5.4	7.04	3.03
12	25 da	6.0		

Part V: TISSUE-ORGAN VS O.P., D.P.D.

	Tissue-Organ	O.P. Beech[1]	Hellebore[2]	Nettle[3]	Tissue-Organ	D.P.D.
	Leaf				Root, absorption zone	
1	Epidermis	15	19.2	18.8	20 Epidermis	0.7
2	Spongy parenchyma	22.4	22.5	24.7	Cortex	
3	Palisade parenchyma	37.7	32.9	37.7	21 1st row	1.4
	Stem				22 2nd row	1.5
4	Cambium	24.6	21.9	21.5	23 4th row	2.1
5	Xylem parenchyma	36.6	22.2	23	24 5th row	2.8
6	Pith		20.6	18.7	25 6th row	3.0
7	Wood rays	35.2			26 Endodermis	1.7
8	Cortex	26.1	20.8	19.2	27 Wood parenchyma	0.9
9	Phloem parenchyma	22.5		20.4		

	Tissue-Organ	D. P. D.
18	Petiole	8.4
19	Stem, 225 cm high	5.0
20	Stem, 35 cm high	2.9
21	Root, older portion	2.4
22	Root, absorption zone	1.6
		O. P.
23	Sieve-tubes	15.6-17.1
24	Stem wood	7.5-11.8
25	Root wood	6.3
26	Stem cambium	11.1-12.9
27	Root cambium	9.7-11.0

/1/ Fagus sp. /2/ Helleborus sp. /3/ Urtica sp.

Part VI: TIME OF DAY VS O.P.

	Species	O.P.; (D.P.D.) 6 AM	10 AM	2 PM	5 PM	8 PM
	King-weed (Ambrosia trifida)					
1	Top leaf	12.5;(7.5)	15.3;(15)	17.4;(17.5)	16.5;(15)	16.3;(15)
2	1st leaf from top	12.5	15.6	17.2	15.7	14.9
3	2nd leaf from top	12.9;(8)	15;(14.5)	17.1;(17)	15.7	14.9;(15)
4	Lowest leaf	10.1;(6.5)	13;(13.5)	15.9;(15.5)	14.3	14;(14)

	Species	8 AM	1 PM	3 PM	7 PM
	Dock (Rumex patientia)				
5	Guard cell	16.6	21	20.2	13.2
6	Subsidiary cell	16.6	16.6	17.8	15.5
7	Epidermal cell	14.4	14.4	14.4	13.2

	Species	12 N	2 PM	4 PM	6 PM	8 PM	10 PM	6 AM	8 AM
	Bluestem (Andropogon scoparius)								
8	Shoots (extreme drought)	23	25	27	26	21.5	20.5	21	25

Part VII: SEASON VS O.P.

	Species	Osmotic Pressure Oct	Dec	Jan	Feb	Mar	Apr	May	June
1	Aspen (Populus tremuloides)	15	16.8	16.2	13.7	17		10.6	
2	Spruce (Picea glauca)	17.1	20.3	20		24.9	20.1	21	19.7
3	Twin-flower (Linnaea borealis)	19.6	25			25.6		14.3	
4	Wintergreen (Pyrola rotundifolia)		24.6		23.9	17.2			12.6

Part VIII: SOIL MOISTURE-SOLUTES VS O.P.

	Soil Water, g/100g	Corn Plant Shoots O.P.	Roots O.P.
1	31	22.1	5.9
2	16	24.4	7.8
3	14	25.0	9.2
4	11	26.5	12.0
	Soil Solution, O.P.	Shoots	Roots
5	1.2	6.2	4.6
6	2.0	7.1	5.5
7	3.4	7.0	6.6
8	5.0	7.2	7.5
9	7.2	7.3	8.2

Part IX: HABITAT VS O. P.

	Habitat	Woody Plants O.P.	Herbaceous Plants O.P.
1	Jamaica		
1	Ruinate	13	10
2	Ridge forest	12	9
3	Leeward ravines	11	8
4	Windward Arizona	10	8
5	Rocky slopes	22	16
6	Canyons	21	13
7	Arroyos	17	13
8	Bajada slopes	30	20
9	Salt spots	45	24

Part X: PLANT GROUPS VS O.P.

	Plant Group	O. P.
1	Summer ephemerals	8-42
2	Succulents and winter ephemerals	4-24
3	Xerophytes	14-57
4	Hydrophytes	8-13
5	Air leaves	18-21
6	Water leaves	6-9
7	Epiphytes	3-6
8	Halophytes	30-115
9	Parasites[1]	14-17
10	Hosts	11-14

/1/ As for example, mistletoe (Phoradendron flavens), 15.8; host, 11.6.

304. OSMOTIC REGULATION: ANIMALS

	Organism	Osmotic Characteristics	Regulatory Mechanisms
1	Marine invertebrate eggs; Phascolosoma	Osmotic adjustment	No volume regulation known.
2	Marine mollusks; maja; Nereis pelagica; N. cultrifera		Volume regulation.
3	N. diversicolor	Limited osmoregulation	Low permeability; salt reabsorption in nephridia.
4	Gunda		Water storage.
5	Carcinus	Fair osmoregulation in hypotonic media	Selective absorption of salts from medium; kidney reabsorption or secretion; low permeability.
6	Uca	Regulation in hypertonic and hypotonic media except at extremes	Unknown.
7	Crayfish; fresh-water teleosts; amphibia	Unlimited (?) regulation in hypotonic media	Hypotonic copious urine; salt reabosprtion or water secretion; low surface permeability.
8	Fresh-water embryos		Water impermeability in some.
9	Elasmobranchs	Maintenance of hypertonicity in both media	Urea retention.
10	Some marine teleosts	Regulation in hypertonic media	Extrarenal salt excretion; low water intake.
11	Artemia		Unknown.
12	Earthworm; amphibians	Regulation in moist air	Low skin permeability; salt absorption from medium; salt reabsorption in kidney.
13	Insects	Regulation in dry air	Impermeable cuticle; hypertonic urine.
14	Birds, reptiles, mammals		Hypertonic urine; water reabsorption in kidney.

305. WATER BALANCE: ANIMALS

Part I: TERRESTRIAL ANIMALS

Values are for the resting state. Body weight values are g; others are g/100g body weight per day.

	Animal	Body Weight g	Water Turnover	Water Intake[1]	Metabolic Water[2]	Output	
						Urine	Other[3]
1	Man	65,000	4.0	3.5	0.5	1.9	2.1
2	Cat	2,900	8.4	7.2	1.2	4.1	4.3
	Cattle						
3	Brahman, dry	409,000	6.1	5.5	0.6		
4	Holstein, dry	745,000	6.7	6.0	0.7		
5	Holstein, milking	529,000	15.9	14.8	1.1		
6	Jersey, milking	403,000	12.8	11.8	1.0		
7	Steer	584,000	4.8	4.0	0.8		
8	Dog	18,600	6.0	4.6	1.4	1.9	3.1
9	Elephant	3,670,000	4.6	4.2	0.4	1.3	3.3
10	Guinea pig	450	17.0	14.5	2.5		
11	Hamster, golden	70	21.6	18.4	3.2		
12	Horse	420,000	6.2	5.5	0.7	1.2	4.3
13	Monkey, rhesus	4,900	8.2	7.0	1.2	5.3	2.9
14	Mouse, albino	21	20.4	10.1	10.3	4.3	16.1
15	Mouse, deer	20	15.4	9.0	6.4		
16	Rabbit	3,670	13.0	11.3	1.7	7.4	5.6
17	Rat, albino	225	16.3	13.9	2.4	5.8[4]	10.5
18	Rat, cotton	130		17.7			
19	Rat, kangaroo	106	8.2	5.5	2.7		
20	Vole	29	27.3	21.1	6.2		
21	Chicken	1,550	16.1	13.0	3.1		

[1] In drink and food. [2] Water of oxidation of foods or body protoplasm. [3] Water lost in sweat, respiratory tract, feces, and incorporation into new protoplasm. [4] A value of 3.8 has been reported.

Part II: AQUATIC ANIMALS

Values are for the resting state. Body volume values are ml and those for water turnover are per cent body volume per day at the indicated temperature.

	Animal	Body Volume ml	Water Turnover % body/day	Temp °C
		In Fresh Water		
	Amphibia			
1	Bufo vulgaris	22	117	
2	Rana esculenta	65	22	
3	Rana pipiens	32	40	20
4	Rana temporaria	9	100	
5	Salamandra	20	53	
6	Triton marmoratus	5	43	
	Insecta			
7	Chironomus larva	0.1	22	
8	Corethra larva	6.2	19	20
	Crustacea			
9	Cambarus	13	5.3	
10	Eriocheir	60	3.6	13
11	Potamobius	46	4.1	
	Annelida			
12	Lumbricus	4	60	19
	Protozoa			
13	Amoeba proteus	$3x10^{-6}$	360	23
14	Cyclidium	$2x10^{-9}$	$2.2x10^{4}$	

	Animal	Body Volume ml	Water Turnover % body/day	Temp °C
	Protozoa (concluded)			
15	Euplotes	$3x10^{-7}$	10^{4}	25
16	Lembus	$2x10^{-9}$	$6x10^{4}$	26
17	Leucophrys	$4.7x10^{-7}$	3,300	21
18	Paramecium	$1.9x10^{-7}$	6,200	22
19	Rhabdostyla	$8x10^{-9}$	$1.1x10^{4}$	15
20	Spirostomum	$2.2x10^{-6}$	550	
21	Zoöthamnium	$1.4x10^{-5}$	5,500	15
		In Sea Water		
	Pisces			
22	Anguilla	250	6.5	
23	Myoxocephalus	180	11.5	
	Crustacea			
24	Cancer	300	6.5	
25	Carcinus	40	10.0	
26	Maia	2,200	2.7	
	Protozoa			
27	Amoeba mira	$6x10^{-9}$	4,300	
28	Cothurnia	$1.2x10^{-8}$	700	15
29	Zoöthamnium marinum	$1.2x10^{-7}$	750	15

Values in parentheses are ranges and unless followed by superscript, are estimate "b" of the 95% range (cf Introduction). * = range is only an estimate from comparable data in other animals.

	Animal	Total Body Water			Extracellular Body Water			Plasma Volume[1]	
		Specifications	ml/kg	Method[2]	Specifications	ml/kg	Method[2]	Specifications	ml/kg
1		Fetus, <100 g	914(871–957)	Des	Infant, premature	435(300–570)	Na^{24}		
2		100–499g	882(837–927)	Des					
3		500–999g	852(792–912)	Des	Infant, full term	391(275–510)	Na^{24}		
4		1000–1499g	832(798–866)	Des		346(275–419)[d]	Inulin[3]	<1 yr	47.7(34.0–61.4)
5		1500–2499g	783(710–856)	Des		353(297–414)[d]	Ferrocy[3]		
6		Newborn	757(703–811)	D_2O	<1 mo	412(354–470)	Thio		
7		1–12 mo	626(509–745)	D_2O	1–12 mo	364(268–460)	Thio		
8		1–10 yr	589(548–630)	D_2O	1–6 yr	309(236–382)	Thio	1–9 yr	46.9(34.8–59.0)
9		10–16 yr ♂	590(516–664)	D_2O	10–18 yr ♂	286(228–344)	Thio	10–18 yr ♂	49.0(37.0–61.0)
10		♀	561(489–633)	D_2O				♀	42.6(30.0–55.2)
11		Adult ♂	635	Des	Adult ♂	248(188–308)	Thio	Adult ♂	46.2(33.7–58.7)
12		♂	592(472–712)	D_2O	♂♀	158(131–185)	Inulin[3]		
13		♂	542(426–658)	AP	♂♀	178(143–213)	Sucrose[3]		
14		♂	532(462–602)	T_2O	♂♀	159(141–189)[d]	Mannitol[3]		
15		♂<70kg	626(517–735)	D_2O	♂<60kg	248(154–342)	Thio		
16	Man	♂>70kg	560(470–650)	D_2O	♂60–69kg	249(196–302)	Thio	♂18–29 yr	46.0(34.7–57.3)
17		♂17–39 yr	602(502–702)	D_2O	♂70–79kg	241(176–306)	Thio	♂30–49 yr	43.8(31.8–55.8)
18		♂40–59 yr	572(471–673)	D_2O	♂>80kg	221(182–260)	Thio	♂50–69 yr	46.0(30.6–61.4)
19		♂>60 yr	541(478–628)[d]	D_2O	♂20–60+ yr	260(220–290)[c]	Cl^{38}	♂>70 yr	48.7(35.3–62.1)
20		♀	560	Des	♀	208(144–272)	Thio	♀	43.5(32.5–54.5)
21		♀	496(404–588)	D_2O	♀40–70+ kg	245(185–305)	Bromide		
22		♀	448(336–556)	AP					
23		♀<60kg	505(415–595)	D_2O	♀<50kg	220(160–280)	Thio		
24		♀>60kg	486(395–577)	D_2O	♀50–69kg	198(138–258)	Thio		
25		♀<40 yr	511(430–592)	D_2O	♀>70kg	183	Thio		
26		♀>40 yr	468(389–547)	D_2O	Pregnant, 1st 1/3	281(196–366)	Thio		
27		♀20–39 yr	444	AP	2nd 1/3	284(221–347)	Thio		
28		♀40–59 yr	446	AP	3rd 1/3	303(233–373)	Thio		
29		♀60–79 yr	422	AP	60–69kg	310(250–370)	Thio		
30		♀>80 yr	488	AP	80–89kg	278(227–329)	Thio		
31		Pregnant, 2nd 1/3	547(485–600)	D_2O	>100kg	241(191–291)	Thio	Pregnant[4]	50.7(36.0–76.8)
32		3rd 1/3	544(485–590)	D_2O					
33		Post-partum	520(435–580)	D_2O					
34		Newborn	807	Des					
35	Cat	2 wk	738	Des					
36		12 wk	666	Des					
39		Adult	580		Adult	288	Thio	Adult	46.4(32.2–56.4)
38	Cattle	Fattened	539(431–647)	AP				Adult	38.8(36.0–41.6)
39		Newborn	779(737–803)[d]	Des	Adult	299(240–360)[d]	Na^{24}		
40		Young	700(670–730)	Des		312(290–340)[c]	Cl^{36}		
41	Dog	Adult, lean	700(615–756)[d]	Des		320(239–408)	Thio	Adult	52.7(35.0–70.4)
42		obese	596(503–690)	Des		198(145–251)	Inulin[3]		
43		unspecified	628(550–662)[d]	Des		216(166–214)	Mannitol[3]		
44	Goat	18.6kg	717	AP					48.0(42–54)[5]
45		44.2kg	706	AP					52.8(45–59)
46		Fetus <12g	894(863–946)[d]	Des					
47	Guinea pig	71–112g	716(684–754)[d]	Des					
48		Newborn	710	Des					
49		Adult	635(524–746)	Des				Adult	43.0
50	Monkey		691(650–720)[d]	Des	Adult	208(121–195)	Thio	Adult	44.9(27.1–62.7)
51		Fetus, 1/2 time	871	Des					
52		Newborn	833	Des					
53	Mouse	15 da	757	Des					
54		30 da	766	Des				Adult	57.4
55		Fetus, <1g	915(914–915)[5]	Des					
56		>50g	816(815–818)[d]	Des					
57	Rabbit	Newborn	830(772–888)*	Des					
58		Young	720(651–767)*	Des					
59		Adult 2.7–4.0kg	667(550–785)	AP	Adult 2.7–4.0kg	246(200–295)	Thio	Adult 2.7–4.0kg	38.0(27–48)
60		Fetus, <0.20g	922(918–926)	Des					
61		0.5–1.0g	900(892–908)	Des					
62		2.5–5.0g	874(867–881)	Des					
63		Newborn	868(851–885)*	Des					
64		6 da	814(773–855)	Des					
65		10–15 da	757(719–795)	Des				Very young	54.7(49.6–59.8)
66	Rat	1–2 mo	697(662–732)*	Des					
67		2–3 mo	684(643–725)*	Des				Pubescent	65.0(59.2–70.8)
68		Adult, lean ♂	690(676–704)*	Des	Adult	300(260–340)	Thio	Adult	41.5(29.5–53.5)
69		♀	684(670–698)*	Des					
70		average ♂	660(620–700)*	Des					
71		♀	650(610–690)*	Des					
72		obese ♂	558(508–608)*	Des					
73		♀	586(516–656)*	Des					
74		♂ 250–390g	674(505–840)	AP	♂ 290–350g	269(190–350)	Thio	♂ 290–350g	45.1(31–59)
75	Swine	Newborn	834	Des					
76		17 da	799(796–802)[d]	Des					

/1/ Measured by the dye method using T-1824 (Evans blue). /2/ AP = antipyrine; Cl^{36}; Cl^{38} = radioactive isotopes of chlorine; Des = desiccation; D_2O = deuterium oxide; Ferrocy = ferrocyanide; Na^{24} = radioactive isotope of sodium; Thio = thiocyanate; T_2O = tritium oxide. /3/ Constant infusion technique. /4/ Third trimester. /5/ Measured by radio-iodinated albumin.

Values in parentheses are ranges and, unless accompanied by superscript, are estimate "b" of the 95% range (cf Introduction)

	Species	Age Group	ERPF[1]		ERPF[2]		Glom. Filtration Rate[3]		Filtration Fraction[4]	Maximum Rate of Tubular Transf (Tm) p-Aminohippurate		Glucose	Clearances[5] Urea[6]	Creatinine[7]
			ml/min	ml/min per sq m S.A.[8]	ml/min	ml/min per sq m S.A.[8]	ml/min	ml/min per sq m S.A.[8]		mg/min per sq m S.A.[8]			ml/min per sq m S.A.[8]	
1	Man	Infant				149		45(26-64)	54	12.9		77	32(20-43)	
2		Full term, 2-8 da				73		38(17-60)	49	14(6-26)			23.2	
3		10-22 da				229		50(32-69)	24	21.4			36	53.4(36-71)
4		1-5 mo				326		77(39-114)	24	51			55(23-88)	
5		6-11 mo				480		103(49-157)	22(8-36)	50			68	
6		12-19 mo				519(419-619)		127(62-191)	25(15-35)	61(19-104)			71	
7		Children, 2-12 yr				654(533-775)		127(89-164)	20(12-28)	74(36-112)		543(285-828)	75(38-112)	
8		Adults[c]		1166		655(544-761)[c]		127(117-140)[c]	19(11-27)	80(46-113)	51.8(34-69)	375(295-455)	75(59-95)	139(115-192)
9		Adults[c]		940		600(518-669)[c]		118(109-127)[c]	20(14-26)	77(56-99)	42.6(24-62)	303(248-358)	75(59-95)	148(115-181)
10		Pregnancy, 2-8 mo		1359(964-1799)		727(590-865)		170(147-193)	22		45.6		104(86-122)	186(102-317)
11		near term		919(632-1773)		561(461-670)		126(69-183)	19.5				79(50-108)	153(120-231)
12	Dog	Adult[9]	300[10]	480	166	265(135-400)	53	84(45-120)	32(26-38)	19	20(13-48)[c]	300(170-390)[c]	56(28-83)	
13	Rabbit	Adult[9]	78	430	54	300(180-410)	9.2	50(30-70)	17		33(30-37)	79(55-105)	25.5	
14	Rat	Adult[9]	8	221	4.4	145	1.7	40(23-56)	28	20	9.3		10.9(5-17)	

/1/ Effective Renal Blood Flow calculated from Effective Renal Plasma Flow = 1 minus hematocrit. /2/ Effective Renal Plasma Flow measured by PAH(p-aminohippurate) or diodrast clearance. Values require upward correction of about 10% for incomplete extraction by kidney to yield values for total renal plasma flow. /3/ Glomerular filtration rate (GFR) measured for man by inulin or mannitol; for dog, rabbit, and rat, by inulin, mannitol or creatinine. /4/ GFR/ERPF (% of plasma filtered). /5/ Minimum volume of blood required to furnish the amount of substance excreted in urine in one minute. /6/ Maximum whole blood clearance, or when urine flow rate is 2 ml or more per minute. Urea concentration in urine x urine flow ÷ urea concentration in blood. /7/ Exogenous. /8/ In clinical medicine, values are usually based on body surface area of 1.73 sq m (adult, 70 kg ♂, 60 kg ♀), whereas for other animals values are per sq m; in this table, values are based on dog 13 kg, 0.623 sq m; rabbit 3 kg, 0.18 sq m; rat 0.2 kg, 0.03 sq m. /9/ Unanesthetized. /10/ Hematocrit = 0.45.

308. KIDNEY CONCENTRATING POWER AND ELECTROLYTE EXCRETION: MAMMALS

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

	Species	Urine Output ml/kg/da	Max. Conc., Urea mOs/L[2]	Max. Conc., Osmolar mOs/L[2]	Maximum Specific Gravity[3]	Max. U/P Osmotic Gradient[4]	Chloride Excretion mEq/da	Chloride Conc. mEq/L	Bicarbonate[1] Excretion mEq/da	Bicarbonate[1] Conc. mEq/L	Phosphate Excretion mEq/da	Phosphate Conc. mEq/L	Sulfate Excretion mEq/da	Sulfate Conc. mEq/L
1	Man	(9-29)	1000	(1200-1400)	1.040	4.2	118(58-250)	110(49-210)	1.5(0-36)	1.1(0-26)	36(22-54)[5]	28(0-120)	37(11-56)	26(13-56)
2	Cat	26(22-30)									22			
3	Cow	14					282(127-610)							
4	Dog	31(25-41)	1600	(1700-3000)	1.060	5.5-10)	40(0-222)	76(0-400)	18(0.01-71)	39(0-150)	7(0-38)	(0-120)	26(1-48)	48(6-800)
5	Rabbit	90(20-300)					3.6(0.8-9.8)	41(3.4-94)			1.4(0.6-2.1)	4.6(1.5-6.9)		
6	Rat	43(24-77)	2400	2400	1.056	8.2	1.3(0.4-1.9)	96(31-144)			0.5(0.27-0.55)		0.17(0.13-0.21)	5.5

	Species	Sodium Excretion mEq/da	Sodium Conc. mEq/L	Potassium Excretion mEq/da	Potassium Conc. mEq/L	Ammonia Excretion mEq/da	Ammonia Conc. mEq/L	Calcium Excretion mEq/da	Calcium Conc. mEq/L	Magnesium Excretion mEq/da	Magnesium Conc. mEq/L	Water Excretion ml/da
7	Man	120(40-186)	114(35-167)	64(53-91)	50(27-150)	38(30-70)	27(20-50)	8(2-18)	7.5(1.4-13)	9(6-16)	8.2(5.8-11.6)	1400(500-3000)
8	Cat							0.11	3.0	0.4	11.9	36
9	Cow	360(89-475)		2370(1650-2980)				18.0(4.5-74.3)		339(154-578)		
10	Dog	32(1-209)	74(2-530)	31(3-128)	84(18-540)	25(2.9-82)	69(4-190)	1.3(0.1-7.0)	2.1(0.2-76)	3.9(0.7-20.7)	8.3(2.8-26.9)	420(122-2000)
11	Rabbit		60					1.7(0.5-3.4)	5.2(1.6-11.4)	2.7	8.5	258(34-935)
12	Rat	1.4(0.2-1.9)	90(35-164)	0.9(0.4-1.9)	118(37-388)	0.7		0.09(0.02-0.16)		0.17(0.04-0.3)		12(4.3-24)

/1/ Bicarbonate excretion is a function of urine pH. For man little is excreted at pH 5.2; 1.5 mEq at 6.0; 6 mEq at 6.6; 14 mEq at 7.0; 36 mEq at 7.4. /2/ Milliosmols per liter. /3/ Specific gravity during imposed thirst (water deprivation for 12 or 24 hours) is a measure of kidney concentrating power used in clinical medicine. /4/ Ration of osmolar concentrations of solutes in urine and plasma. /5/ Base equivalence assumed as 1.0. Proportion of BH_2PO_4 to B_2HPO_4 varies with pH of urine. At pH 5.4, proportion is 0.96 to 0.04, and the base equivalence is 1.04. At pH of plasma, the proportion is 0.2 to 0.8, and the equivalence is 1.8.

309. GASTRIC SECRETION, TESTS: MAN

Values in parentheses are ranges, and, unless followed by superscript, are estimate "d" of the 95% range (cf Introduction).

	Condition	Age Group	Volume ml/hr	Free HCl mEq/liter[1]	Total HCl mEq/liter[1]	pH	Pepsin units/ml[2]	Mucin mg/100 ml
1		Adult, 20-39 yr, ♂	77(0-164)	32(0-95)				
2		♀	70(0-160)	24(0-74)				
3		40-59 yr, ♂	84(0-176)	30(0-87)	66(13-118)[3]	♂♀(2.2-2.7)[3, 4]	♂♀65(0-162)[3]	♂♀181(11-351)[3]
4	Fasting	♀	66(0-155)	17(0-74)	43(5-70)[3]			
5		60-79 yr, ♂	65(0-149)	16(0-60)				
6		♀	48(0-103)	10(0-32)				
7		Adult, 20-59 yr, ♂	79(0-176)	26(0-95)				
8	Basal, one hour	♀	65(0-160)	20(0-74)				
9	Nocturnal	Adult[3] ♂	54(14-99)	30(1-90)		♂♀(1.1-2.6)	♂♀205[5]	
10		♀	38(12-75)	27(3-72)				
11		Adult, 20-39 yr, ♂	114(13-217)	47(13-80)	62(29-96)			
12		♀	99(20-178)	33(4-61)	50(21-80)			
13		40-59 yr, ♂	99(13-192)	44(6-79)	58(19-96)	(1.6-1.8)[3]	♂♀7(3-15)[3, 6]	
14	After test meal	♀	93(16-172)	33(6-62)	50(20-80)			
15		60-79 yr, ♂	91(0-192)	36(0-76)	52(17-91)			
16		♀	82(13-156)	33(1-65)	50(16-85)			
17		Children, 6-11 mo, ♂♀	18(6-54)[c]	(0-50)[c]	(8-110)[c]	(1.3-1.5)		
18		1-15 yr, ♂♀	50(6-180)[c]	(15-115)[c]	(26-145)[c]	(1.2-2)		
19		Adult, 20-39 yr, ♂	131(6-256)	76(11-142)				
20	After histamine	♀	99(2-203)	62(0-124)				
21		40-59 yr, ♂	137(0-283)	69(0-156)			32[3]	♂♀136(0-330)[3]
22		♀	101(0-229)	53(0-125)			43[3]	
23		60-79 yr, ♂	108(0-257)	44(0-130)				
24		♀	84(0-195)	45(0-113)				
25	After insulin	Adult[3] ♂	140(85-204)	123(103-140)	128(111-144)	♂♀(1.2-1.8)	58	♂♀225(83-367)
26		♀	109(70-148)	123(105-133)	128(112-138)			

/1/ One mEq/liter is the same as one "clinical unit" or one "degree of acidity" = ml of 0.1 N NaOH required to neutralize 100 ml of gastric secretion. /2/ Unless otherwise indicated, "units" refer to proteolytic units in the Anson and Mirsky method. /3/ Age not specified. /4/ Range of means. The range for one normal person may be 1.5-5.0. /5/ Micrograms per ml (refers to equivalent activity of a standard pepsin). /6/ mg/ml (refers to equivalence to a standard pepsin).

310. LIVER FUNCTION, TESTS: MAN

Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

	Test or Constituent	Method	Normal Values	Abnormal Levels
	Tests Related to Bilirubin Metabolism			
1	Serum bilirubin, total	Van den Bergh	<0.2 mg/100 ml	Increased
2	Serum bilirubin, total	Photoelectric	0.25-1.5 mg/100 ml	Increased
3	Serum bilirubin, direct	Photoelectric	0-1.5 mg/100 ml	Increased
4	Icterus index	Acetone	1-5 units	Increased
5	Bilirubin clearance	I.V. injection	<5% retention at 4 hr	>5% retention
6	Urobilinogen, urine	Quantitative	<4 mg in 24 hr	Increased[1]
7	Urobilinogen, urine	Simplified quantitative	<1.9 "Ehrlich units" in 2 hr	Increased[1]
8	Urobilinogen, fecal	Quantitative	40-280 mg in 24 hr	Increased; decreased[2]
	Dye Excretion Tests			
9	Bromsulfalein	Photoelectric; dose 5 mg/kg	<5% at 45 min	>6%
10	Rose Bengal	Spectroscopic	<55% at 8 min	>55%
	Tests Related to Carbohydrate Metabolism			
11	Galactose tolerance	Urine, after oral administration	<3 g in 5 hr	>3 g[3]
12	Galactose tolerance	Blood, after I.V. administration	0 at 75 min	Positive[3]
13	Levulose tolerance	Blood, after I.V. administration	<20 mg at 1 hr	>20 mg
14	Lactic acid tolerance	Blood, after I.V. administration	<5 mg at 30 min	>5 increased[1]
	Tests Related to Protein Metabolism			
15	Serum albumin	Sodium sulfate	4.8%(3.6-5.6) g/100 ml	Decreased
16	Serum globulin	Sodium sulfate	2.12(2.0-3.7) g/100 ml	Increased
17	Albumin/globulin	Sodium sulfate	2.31(1.5-2.5) g/100 ml	Decreased
18	Zinc turbidity	Zinc sulfate	6-12.5 units	>12.5 units
19	Prothrombin	Quick	70-100% of normal control	Decreased
20	Prothrombin response	Response to vitamin K	>10% rise in prothrombin	<10% rise
21	Cephalin flocculation[4]	Hanger	<2+, 24 hr; up to 2+, 48 hr	3-4+, 48 hr
22	Thymol turbidity	MacLagan	<5 units at 30 min	>5 units
23	Thymol flocculation	Neefe	0-1 plus at 18 hr	2+ or more
24	Colloidal Red	Ducci	0-1 plus at 24 hr	>2+
25	Takata-ara		No flocculation	Flocculation
	Tests Related to Lipid Metabolism			
26	Cholesterol, total	Chemical	194-235 mg/100 ml	Increased[4]
27	Cholesterol, esterified	Chemical	70-79% of total cholesterol	<50% total cholesterol
28	Phospholipid	Chemical	145-280 mg/100 ml	Increased; decreased[3]
29	Lipids, total	Chemical	591-720 mg/100 ml	Increased; decreased[3]
	Miscellaneous Tests			
30	Serum alkaline phosphatase	Bodansky	1-4 units	>4 units[2]
31	Serum cholinesterase	Potentiometric (Michel)	0.66-1.06	Decreased
32	Hippuric acid	Sodium benzoate; 3 g, oral	2.5-3.5 g in urine after 4 hr	Decreased

/1/ In liver disease and hemalytic states. /2/ In complete obstruction of biliary passages. /3/ Parenchymal liver damage. /4/ Cephalin cholesterol.

T emperatures are daytime rectal or cloacal averages.

	Species	Temperature, °C		Species	Temperature, °C
1	Man (Homo sapiens)	36, 9(36, 2-37, 6)	84	Jackal (Canis aureus indicus)	38, 3
2	Agouti (Dasyprocta acouchy)	38, 9(38, 7-39, 0)	85	Kangaroo, red (Macropus rufus)	35, 8(35, 0-36, 8)
3	Agouti (D. aguti)	38, 5(37, 9-39, 0)	86	Kangaroo, great gray (M. major)	36, 0(34, 7-36, 0)
4	Agouti (D. azarae)	39, 0(38, 9-39, 1)	87	Kinkajou (Potos caudivolvulus)	36, 8(36, 4-37, 2)
5	Agouti (D. prymnolopha)	38, 9(37, 9-39, 0)	88	Koala (Phascolarctos cinereus)	36, 4(34, 9-38, 4)
6	Anteater, three-toed (Tamandua tetradactyla)	33, 8(32, 9-35, 2)	89	Lemming, collared (Dicrostonyx rubricatus)	38, 3(35, 4-41, 2)
7	Anteater, two-toed (Cyclopes sp)	30, 7(30, 2-31, 1)			
8	Ape (Cynopithecus niger)	37, 9(37, 1-38, 8)	90	Lemur (Lemur variegatus)	38, 2(37, 5-38, 9)
9	Armadillo (Dasypus villosus)	31, 3(30, 0-32, 5)	91	Loris (Perodicticus potto)	36, 9(34, 9-38, 9)
10	Armadillo (D. novemcinctus)	32, 5(30, 0-32, 5)	92	Macaque (Macaca maccaus)	38, 4(36, 4-40, 0)
11	Armadillo (D. sexcinctus)	33, 2(32, 2-35, 0)	93	Manatee (Trichechus manatus)	39, 5[2]
12	Armadillo (D. villosus)	33, 4(31, 8-35, 0)	94	Marmot (Actomys marmota)	34, 2(31, 2-37, 2)
13	Ass (Equus asinus taeniopus)	37, 4(37, 0-37, 8)	95	Marmot (Marmota marmota)	36, 2(31, 2-39, 0)
14	Baboon (Papio hamadryas)	38, 1(37, 2-38, 7)	96	Marmot, hoary (M. caligata)	36, 4(33, 5-39, 3)
15	Bat (Eptesicus fuscus)	38, 1(36, 2-40, 0)	97	Mole, common (Scalopus aquaticus)	35, 8(34, 6-37, 0)
16	Bat (Pipistrellus noctula)	31, 5(30, 0-33, 0)	98	Monkey (Macaca mulatta)	38, 8(37, 2-40, 2)
17	Bat (Plecotus auritus)	36, 6(35, 0-38, 2)	99	Monkey (M. sylanomolgus)	37, 8(36, 7-38, 5)
18	Bat, big brown (Eptesicus tenuipinnis)	35, 7(32, 2-39, 2)	100	Monkey (Papio hamadryas)	38, 1(37, 3-38, 7)
19	Bat, big brown (E. serotinus)	38, 1(36, 2-40, 0)	101	Monkey, night (Aotes trivirgatus)	38, 2(37, 4-40, 0)
20	Bat, horseshoe (Hipposideros caffra)	34, 9(31, 4-38, 4)	102	Monkey, velvet (Cercopithecus patus)	38, 0(37, 4-38, 5)
21	Bat, horseshoe (H. cyclops)	34, 8(31, 4-38, 2)	103	Monkey, velvet (C. pygerythrus)	38, 7(36, 9-40, 5)
22	Bat, horseshoe (Rhinolophus ferrum-equinum)	35, 8(29, 1-42, 5)	104	Moose (Alces americana)	39, 4
23	Bat, horseshoe (R. hipposideros)	35, 9(34, 4-37, 4)	105	Mouse, deer (Peromyscus leucopus)	37, 4(33, 6-41, 2)
24	Bat, horseshoe (R. landeri)	32, 8(28, 0-37, 6)	106	Mouse, deer (P. maniculatus)	37, 9(35, 7-40, 1)
25	Bat, little brown (Myotis myotis)	37, 6(35, 6-39, 6)	107	Mouse, house (Mus musculus)	36, 5(35, 2-37, 9)
26	Bat, little brown (M. mystacinus)	37, 2(36, 2-38, 2)	108	Mouse, jumping (Zapus hudsonicus)	37, 3(35, 3-39, 3)
27	Bat, short-tailed (Carollia perspicillatum)	37, 4(36, 4-37, 8)	109	Mouse, meadow (Microtus pennsylvanicus)	39, 3(34, 7-43, 1)
28	Bear, black (Ursus americanus)	38, 3(31, 3-39, 0)	110	Mouse, pocket (Perognathus hispidus)	36, 5(34, 9-38, 1)
29	Bear, brown (U. arctos)	38, 0(37, 0-39, 1)	111	Mouse, red-backed (Clethrionomys gapperi)	37, 3(35, 3-39, 3)
30	Bear, polar (U. -Thalarctos-maritimus)	37, 5(37, 1-37, 8)	112	Mouse, red-backed (C. rutilus)	38, 3(36, 6-40, 0)
31	Bison (Bison bison)	39, 0	113	Muntjac (Muntiacus muntjac)	38, 6
32	Buffalo, water (Bubalus spp)	38, 2(37, 4-38, 7)	114	Musk ox (Ovibos moschatus)	40, 0
33	Camel (Camelus bactrianus)	37, 5(36, 9-38, 0)	115	Muskrat (Ondatra zibethica)	38, 0(37, 0-39, 1)
34	Caribou (Rangifer tarandus stonei)	39, 0(38, 5-40, 0)	116	Nutria (Myocastor coypus)	38, 0(37, 2-38, 8)
35	Cat (Felis catus)	38, 1(37, 2-39, 9)	117	Opossum (Didelphis marsupialis)	36, 6(34, 9-36, 4)
36	Cat, ring-tail (Bassariscus astutus)	37, 6(37, 2-37, 9)	118	Opossum (D. virginiana)	34, 2(32, 6-36, 6)
37	Cat, tiger (Dasyrurus maculatus)	35, 6(32, 2-37, 2)	119	Opossum, brown (Metachirus nudicaudatus)	34, 4(32, 4-36, 4)
38	Chimpanzee (Pan troglodytes)	37, 2(36, 3-37, 8)	120	Opossum, brush-tail (Trichosurus vulpecula)	36, 1(35, 4-36, 8)
39	Chipmunk (Tamias striatus)	38, 6(36, 5-40, 1)	121	Opossum, Murine (Marmosa mexicana)	32, 7(28, 9-36, 5)
40	Chipmunk, least (Eutamias minumas)	38, 7(35, 8-41, 6)	122	Opossum, ring-tail (Pseudocheirus vulpina)	35, 1(33, 1-36, 6)
41	Coati (Nasua rufa)	38, 2(37, 1-39, 2)	123	Orangutan (Pongo pygmaeus)	37, 0(36, 2-37, 8)
42	Cow, beef (Bos taurus)	38, 3(36, 7-39, 1)	124	Otter, sea (Enhydra lutris)	38, 5
43	Cow, dairy (B. taurus)	38, 6(38, 0-39, 3)	125	Panther (Felis concolor)	38, 1(37, 2-39, 1)
44	Cow, Holstein	39, 6(38, 2-41, 0)	126	Peccary (Tayassu angulatus)	38, 7
45	Cow, Jersey	39, 3(37, 9-40, 7)	127	Pig (Sus scrofa)	39, 3(38, 7-40, 3)
46	Deer (Odocoileus virginianus)	38, 2(37, 9-38, 5)	128	Pika, collared (Ochotona collaris)	39, 0
47	Dog (Canis familiaris)	38, 9(36, 7-40, 6)	129	Platypus (Ornithorhynchus paradoxus)	30, 5(24, 8-35, 3)
48	Dog, Eskimo (C. familiaris)	38, 5(37, 2-40, 0)	130	Porcupine (Coendou vilosus)	36, 8(35, 3-38, 3)
49	Dormouse (Glis glis)	35, 5(35, 1-35, 9)	131	Porcupine (Erethrizon dorsatum)	37, 4(36, 5-38, 3)
50	Dormouse (Muscardinus avellanaris)	34, 5(31, 0-37, 9)	132	Rabbit (Oryctolagus cuniculus)	38, 8(37, 5-40, 1)
51	Echidna (Tachyglossus sp)	29, 9(24, 9-34, 5)	133	Rabbit, cottontail (Sylvilagus floridanus)	39, 4(38, 7-40, 1)
52	Echidna (T. aculeatus)	29, 4(27, 4-31, 4)	134	Raccoon (Neyctoreutes procyonoides)	37, 4(37, 2-37, 8)
53	Echidna (T. hystrix)	28, 7(25, 7-31, 7)	135	Raccoon (Procyon lotor)	38, 3(37, 3-39, 7)
54	Echidna (Zaglossus sp)	29, 0(26, 2-31, 8)	136	Rat (Rattus rattus)	35, 1(32, 1-38, 1)
55	Eland (Taurotragus oryx)	38, 8	137	Rat, spiny (Proechimys semispinosis)	37, 9(35, 9-39, 3)
56	Elephant (Elephas maximus)	36, 2(35, 7-37, 8)	138	Rat, white (Rattus norvegicus)	37, 3(34, 5-40, 0)
57	Ferret (Mustela putorius)	39, 3(37, 9-40, 4)	139	Reedbuck (Redunca arundinum)	38, 4
58	Fox (Vulpes melanotus)	37, 9(36, 5-39, 3)	140	Reindeer (Rangifer tarandus)	38, 8(37, 5-39, 8)
59	Fox, Alaska red (V. vulpes alascensis)	40, 1	141	Rhinoceros (Rhinoceros unicornis)	37, 6(37, 4-37, 8)
60	Fox, Arctic (Alopex sp)	38, 6(35, 4-41, 8)	142	Seal, Californias ursinus)	38, 3(37, 4-39, 5)
61	Fox, Arctic (Vulpes lagopus)	38, 7(38, 1-39, 3)	143	Seal, bearded (Erignathus barbatus)	37, 2(36, 8-37, 3)
62	Fox, Arctic white (Alopex lagopus)	38, 6(36, 6-41, 5)	144	Sealion, Steller's (Eumetopias jubata)	38, 5
63	Fox, flying (Pteropus gaddei)	35, 4(32, 2-38, 6)	145	Sheep (Ovis aries)	38, 8(37, 2-40, 5)
64	Fox, flying (Rousettus angolensis)	36, 5(34, 4-38, 6)	146	Shrew, short-tail (Blarina brevicauda)	35, 7(34, 6-37, 7)
65	Fox, red (Vulpes fulva)	38, 8(37, 5-40, 1)	147	Skunk (Mephitis mesomelas)	36, 4(36, 3-36, 5)
66	Fox, red (V. vulpes)	37, 8(37, 6-38, 0)	148	Sloth, three-toed (Bradypus cucculiger)	31, 0(24, 4-37, 6)
67	Goat (Capra hircus)	39, 5(38, 3-40, 8)	149	Sloth, three-toed (B. griseus)	33, 2(29, 9-37, 7)
68	Goat, domestic (C. sp)	39, 2(37, 8-40, 5)	150	Sloth, two-toed (Choloepus hoffmanni)	34, 5(33, 4-35, 8)
69	Goat, Indian (C. sp)	38, 6(35, 2-40, 5)	151	Squirrel, Arctic ground (Citellus undulatus)	38, 5(32, 5-41, 0)
70	Goat, mountain (Oreamnos americanus)	38, 6(37, 8-39, 0)	152	Squirrel, flying (Glaucomys volans)	37, 0(35, 0-39, 0)
71	Gopher, pocket (Geomys bursarius)	34, 8(33, 8-35, 8)	153	Squirrel, Franklin (Citellus franklini)	36, 6(33, 9-39, 3)
72	Guinea pig (Cavia sp)	39, 1(38, 4-39, 8)	154	Squirrel, red (Tamiasciurus hudsonicus)	39, 6(37, 6-41, 6)
73	Guinea pig (C. porcellus)	37, 9(36, 0-40, 5)	155	Squirrel, thirteen-lined (Citellus tridecemlineatus)	36, 9(33, 0-40, 8)
74	Hamster (Citellus auratus)	36, 9(36, 4-37, 4)			
75	Hamster (Mesocricetus auratus)	36, 0(35, 0-37, 0)	156	Squirrel, Yukon ground (Citellus parryii)	38, 1(35, 5-40, 7)
76	Hare, Arctic (Lepus timidus)	38, 3	157	Wallaby (Petrogale xanthopus)	36, 0(35, 4-36, 6)
77	Hare, showshoe (L. americanus)	38, 5(38, 0-39, 0)	158	Walrus (Odobenus divergens)	36, 1
78	Hare, varying (L. americanus)	39, 6(38, 9-40, 3)	159	Weasel, least (Mustela rixosa)	40, 4(38, 4-42, 4)
79	Hare, white (L. timidus)	38, 7(38, 1-39, 3)	160	Whale, blue (Balaenoptera musculus)	35, 7(35, 6-35, 8)
80	Hedgehog (Erinaceus europaeus)	35, 1(32, 0-36, 5)	161	Whale, fin (B. physalus)	36, 3(34, 4-38, 2)
81	Hippopotamus (Hippopotamus amphibius)	25, 0[1]	162	Whale, gray (Rachianectes glaucus)	36, 5(35, 0-38, 0)
82	Horse (Equus caballus)	37, 7(37, 2-38, 1)	163	Whale, humpback (Megaptera nodosa)	36, 3(35, 2-37, 8)
83	Hutia (Capromys pilorides)	38, 3(36, 2-40, 3)	164	Whale, sperm (Physeter catodon)	35, 8(34, 6-37, 0)
			165	Wolf (Canis lupus)	40, 5

[1] Skin temperature. [2] Old report; may be for a seal.

Temperatures are cloacal averages taken usually at room temperatures.

	Species	Temperature, °C		Species	Temperature, °C
1	Albatross, wandering (Diomedea exulans)	40, 7(39, 5-41, 9)	81	Hawk, marsh (Circus hudsonius)	41, 9(41, 4-42, 4)
2	Albatross, yellow-nosed (Thalassogeron chlororhynchus)	41, 0(40, 7-41, 3)	82	Hawk, red-tailed (Buteo borealis)	41, 2(40, 9-41, 4)
3	Amazon, blue-fronted (Amazona aestiva)	41, 0[1]	83	Heron, black-crowned night (Nycticorax nycticorax hoactli)	42, 3(41, 9-42, 4)
4	Auk, razor-billed (Alca torda)	39, 1[1](39, 9-41, 1)	84	Ibis, white (Guara alba)	42, 3(42, 2-42, 4)
5	Bittern, American (Botaurus lentiginosus)	40, 2[1]	85	Jackdaw (Coloeus monedula)	41, 2(41, 0-42, 6)
6	Bittern, sun (Eurypyga helias)	39, 1[1]	86	Jaeger, parasitic (Stercorarius parasiticus)	41, 2
7	Blackbird, rusty (Euphagus carolinus)	42, 3[1]	87	Jay, blue (Cyanocitta cristata)	43, 6(42, 0-44, 4)
8	Bluebird, eastern (Sialia sialis)	42, 6(42, 2-43, 0)	88	Jay, brown (Psilorhinus morio)	43, 3[1]
9	Bobolink (Dolichonyx oryzivorus)	42, 6(40, 9-43, 4)	89	Junco, slate-colored (Junco hyemalis)	43, 0(41, 2-44, 0)
10	Brant (Branta bernicla)	42, 7[1]	90	Kittiwake (Rissa tridactyla)	41, 9(39, 9-42, 2)
11	Bullfinch (Pyrrhula pyrrhula)	42, 2	91	Kiwi, large gray (Apteryx haasti)	38, 1[1]
12	Bunting, snow (Plectrophenax nivalis)	43, 1(42, 9-43, 4)	92	Kiwi, north island (A. mantelli)	37, 8(37, 4-38, 2)
13	Bunting, yellow (Emberiza citrinella)	43, 2	93	Knysna Lourie (Tauracus corythaix)	40, 1[1]
14	Cardinal, red-crested (Paroaria cucullata)	44, 2[1]	94	Lark, northern horned (Otocoris alpestris)	43, 9[1]
15	Cassowary, Beccari's (Casuarius beccarii)	39, 2	95	Motmot, Brazilian (Momotus parsenais)	40, 9[1]
16	Cassowary, two-wattled (C. bicaruncula tus intensus)	38, 8	96	Murre (Uria troille)	40, 3(39, 4-41, 0)
17	Catbird (Dumetella carolinensis)	41, 2(40, 0-42, 3)	97	Murre, Atlantic (U. aalge)	40, 9(40, 4-41, 4)
18	Chickadee, black-capped (Penthestes atricapillus)	43, 8(43, 2-44, 3)	98	Murre, thick-billed (U. lomvia)	40, 5(39, 7-41, 5)
19	Chough, Alpine (Pyrrhocorax alpinus)	42, 0	99	Ostrich (Struthio camelus)	39, 2(37, 8-40, 0)
20	Coot, European (Fulica atra)	40, 5[1]	100	Owl, great-horned (Bubo virginianus)	40, 5(40, 3-40, 8)
21	Cormorant, common (Phalacrocorax carbo)	39, 6(38, 9-40, 3)	101	Owl, northern barred (Strix varia)	40, 0(39, 6-40, 5)
22	Cormorant, double-crested (P. auritus)	41, 3(41, 0-41, 5)	102	Owl, snowy (Nyctea nyctea)	41, 0(40, 4-41, 7)
23	Cowbird (Molothrus ater)	43, 2(42, 5-43, 5)	103	Peacock (Pavo cristatus)	40, 0(39, 5-40, 3)
24	Crane, demoiselle (Anthropoides virgo)	41, 1[1]	104	Pelican, white (Pelecanus erythrorhynchos)	40, 5[1]
25	Crane, sandhill (Grus canadensis)	41, 3(41, 0-41, 4)	105	Penguin, little (Eudyptula minor)	39, 0(37, 8-40, 1)
26	Crossbill, red (Loxia curvirostra pusilla)	43, 3(43, 1-43, 6)	106	Petrel, pintado (Daption capensis)	39, 8(39, 3-40, 2)
27	Crossbill, white-winged (L. leucoptera)	43, 0(42, 5-44, 0)	107	Petrel, snow (Pagophila eburnea)	40, 4(39, 9-41, 2)
28	Crow, eastern (Corvus brachyrhynchos)	43, 0[1]	108	Petrel, storm (Hydrobates pelagica)	39, 7[1]
29	Curassow, black (Crax nigra)	42, 0	109	Pewee, eastern wood (Myiochanes virens)	41, 6(39, 6-43, 0)
30	Curassow, Central American (C. rubra)	41, 3	110	Pheasant, Amherst (Chrysocolphus sammerstiae)	42, 2(41, 9-42, 4)
31	Dove, eastern turtle (Streptopelia decaocto)	43, 3(43, 0-43, 9)	111	Pheasant, golden (C. pictus)	42, 5(42, 2-42, 5)
32	Dove, mourning (Zenaidura macroura)	43, 4(42, 9-43, 6)	112	Pheasant, ring-necked (Phasianus colchicus mongolicus)	42, 1(41, 7-42, 4)
33	Dove, quail (Oreopelia montana)	43, 3[1]	113	Pheasant, ring-necked (P. torquatus)	41, 5
34	Duck, black (Anas rubripes)	41, 0(40, 7-41, 5)	114	Pheasant, silver (Gennaeus nycthemerus)	42, 3(42, 2-42, 4)
35	Duck, domestic (A. platyrhynchos domesticus)	41, 5(40, 9-42, 0)	115	Pigeon, Cape Rock (Columba phaeonota)	43, 3[1]
36	Duck, mallard (A. platyrhynchos)	43, 1(42, 8-43, 4)	116	Pigeon, domestic (C. livia)	41, 1(39, 9-41, 9)
37	Duck, muscovy (Cairina moschata)	42, 0(40, 8-42, 3)	117	Pintail (Dafila acuta tzitzihoa)	43, 0(42, 8-43, 2)
38	Duck, shield (Tadorna tadorna)	42, 7(42, 4-42, 9)	118	Puffin, Atlantic (Fratercula arctica)	40, 8(40, 7-40, 8)
39	Duck, wood (Aix sponsa)	42, 0	119	Quail, Calif, (Lophortyx californica vallicola)	42, 9[1]
40	Eider, American (Somateria mollissima dresseri)	42, 5(40, 1-43, 2)	120	Rail, clapper (Rallus crepitans)	40, 1
41	Emu (Dromiceius novaehollandiae)	39, 0	121	Redwing (Agelaius phoeniceus)	42, 7(42, 1-43, 0)
42	Falcon, prairie (Falco mexicanus)	41, 4[1]	122	Road runner (Geococcyx californianus)	41, 9
43	Field fare (Turdus pilaris)	43, 6	123	Robin, eastern (Turdus migratorius)	43, 6(43, 2-44, 2)
44	Finch, eastern purple (Carpodacus purpureus)	43, 2(42, 5-43, 8)	124	Scaup, greater (Marila marila)	42, 6(42, 2-43, 2)
45	Finch, green (Ligurinus chloris)	41, 5(41, 2-42, 2)	125	Scoter, black (Oidemia nigra)	41, 3(40, 9-41, 7)
46	Flamingo (Phoenicopterus chilensis)	40, 5(40, 4-40, 6)	126	Screech-owl, eastern (Otus asio naevius)	40, 1[1]
47	Fowl, domestic (Gallus gallus)	41, 4(40, 9-41, 9)	127	Shag (Phalacrocorax graculus)	40, 4(39, 4-40, 9)
48	Francolin, gray-winged (Francolinus natalensis)	42, 2	128	Shearwater, slender-billed (Puffinus tenuirostris)	38, 6(37, 8-39, 6)
49	Fulmar (Fulmarus glacialis)	38, 8(38, 1-39, 6)	129	Sheathbill (Chionis minor)	40, 0
50	Gadwall (Anas strepera)	42, 9[1]	130	Skua (Megalestris skua)	40, 1(39, 5-40, 8)
51	Gannet (Moris bassana)	40, 9(40, 2-41, 5)	131	Snow-goose, greater (Chenhyperbores atlantica)	40, 8(40, 6-41, 2)
52	Goldeneye (Clangula clangula)	40, 4[1]	132	Sparrow, Cassin's (Aimophila cassinii)	42, 2[1]
53	Goose, barnacle (Branta leucopsis)	40, 2(39, 9-41, 5)	133	Sparrow, eastern chipping (Spizella passerina)	41, 7(39, 8-42, 9)
54	Goose, bean (Anser fabalis)	40, 9	134	Sparrow, eastern fox (Passerella iliaca)	43, 8(42, 7-44, 3)
55	Goose, blue (Chen caerulescens)	40, 4(40, 2-40, 8)	135	Sparrow, eastern song (Melospiza melodia)	41, 1(40, 2-43, 0)
56	Goose, cackling (Branta canadensis minima)	41, 1(40, 7-41, 5)	136	Sparrow, eastern tree (Spizella arborea)	43, 0(42, 3-44, 0)
57	Goose, Canada (B. canadensis)	40, 5(39, 8-41, 3)	137	Sparrow, house (Passer domesticus)	41, 5(37, 3-43, 5)
58	Goose, Chinese (Cygnopsis cygnoides)	42, 8(42, 4-43, 3)	138	Sparrow, Lincoln's (Melospiza lincolnii)	43, 6
59	Goose, domestic (Anser anser domesticus)	41, 3(40, 2-42, 0)	139	Sparrow, sharp-tailed (Passerherbulus caudacutus)	42, 9
60	Goose, Hutchins (Branta canadensis hutchinsi)	40, 5(40, 0-41, 0)	140	Sparrow, white-crowned (Zonotrichia leucophrys)	43, 4(41, 4-44, 7)
61	Goose, white-fronted (Anser albifrons)	40, 5(40, 6-42, 7)	141	Sparrow, white throated (Z. albicollis)	43, 2(41, 5-44, 2)
62	Goshawk, crested (Accipiter trivirgatus)	41, 8(40, 2-42, 2)	142	Sparrow hawk (Falco sparvarius)	42, 3(42, 0-43, 2)
63	Grackle, bronzed (Quiscalus quiscula aeneus)	43, 5(42, 5-44, 0)	143	Starling (Sturnus vulgaris)	43, 5(38, 8-43, 7)
64	Grosbeak, Canadian pine (Pinicola enucleator leucura)	42, 6(42, 0-43, 2)	144	Swan, black (Chenopsis atratra)	40, 6(40, 0-41, 0)
65	Grosbeak, eastern evening (Hesperiphona vespertina)	43, 3(42, 8-43, 9)	145	Swan, mute (Cygnus olor)	41, 0(40, 9-41, 2)
66	Grosbeak, rose-breasted (Hedymeles ludivicianus)	43, 6(43, 2-43, 9)	146	Swift, European (Micropus apus)	44, 0
67	Grouse, ruffed (Bonasa umbellus togata)	42, 5[1]	147	Thrasher, brown (Toxostoma rufum)	43, 1[1]
68	Guillemot, black (Cepphus grylle)	40, 7(40, 6-41, 0)	148	Thrush, red-winged (Turdus musicus)	41, 0(38, 4-42, 7)
69	Guinea fowl (Numida meleagris)	42, 2(42, 0-43, 3)	149	Thrush, wood (Hylocichla mustelina)	42, 9(39, 2-42, 1)
70	Gull, American herring (Larus argentatus smithsonianus)	41, 4(40, 8-41, 9)	150	Tinamou, rufescent (Rhynchotus rufescens)	40, 8
71	Gull, black-headed (L. ridibundus)	41, 4[1]	151	Tinamou, spotted (Nothura maculosa)	40, 5(39, 2-42, 4)
72	Gull, common (L. canus)	42, 1(41, 0-42, 0)	152	Titmouse, great (Parus major)	44, 0
73	Gull, glaucous (L. hyperboreus)	40, 8(39, 8-41, 7)	153	Tree-duck, black-bellied (Dendrocygna autumnalis)	42, 3[1]
74	Gull, great black-backed (L. marinus)	41, 9(41, 2-42, 4)	154	Turkey (Meleagris gallopavo)	42, 8
75	Gull, herring (L. argentatus)	42, 3(41, 6-43, 0)	155	Vulture, bearded (Gypaetus barbatus)	41, 0
76	Gull, laughing (L. atricilla)	42, 3(41, 7-42, 8)	156	Warbler, Connecticut (Oporornis agilis)	42, 1[1]
77	Gull, lesser black-backed (L. fuscus)	41, 7(41, 2-42, 1)	157	Waxwing, Bohemian (Bombycilla garrula)	42, 5(41, 2-42, 1)
78	Hawk, Amer. rough-legged (Buteo lagopus johannis)	42, 0(41, 9-42, 0)	158	Waxwing, cedar (B. cedrorum)	42, 9(42, 0-44, 4)
79	Hawk, broad-winged (B. platypterus)	41, 0[1]	159	Wigeon, European (Mareca penelope)	42, 5(41, 4-43, 0)
80	Hawk, rough-legged (Archibuteo lagopus)	41, 0[1]	160	Wren, eastern house (Troglodytes aedon)	41, 1(39, 2-42, 1)

[1] Only one measurement recorded.

Hibernation in mammals is defined as a state characterized by a lowering of body temperature to near that of the environment with a concurrent decrease in metabolism, but with the ability to regain the elevated body temperature without heat from external sources. Among reptiles and amphibians hibernation is arbitrarily defined as the state where body temperature approaches or equals ambient temperature, and metabolic, respiratory and heart rates are greatly reduced.

	Species	Geographical Distribution	Temperature Air °C	Temperature Rectal °C	Heart Rate per min	Respiration Rate per min	O_2 Consumption ml/g/hr[1]	CO_2 Produced ml/g/hr	RQ[2]
	Mammalia								
	Insectivora								
1	Hedgehog (Erinaceus europaeus)	Great Britain to Spain, Italy,	2-3	6.2-7.7	18-24		0.014-0.033		
2		Greece	3.5	5			0.88	0.83	0.68
3			6				0.40	0.29[3]	0.73
4			9.7	12.0			0.126	0.056	
	Chiroptera								
5	Bat, big brown (Eptesicus fuscus)	U.S.A., southern Canada	8	9		$3\text{-}10^4$			
6			22-26				0.8		
7	Bat, little brown (Myotis lucifugus)	Northern U.S.A., southern	23	23.2		72-80	0.45		
8		Canada, and southern	0.5				0.113		
9		Alaska		2	7-10		0.022-0.039		
10	Bat, greater horseshoe (Rhinolophus	England to Korea, Japan	13	13			0.150	0.089	
11	ferrum-equinum)	to Morocco	19	19			0.426	0.366	0.77
12	Bat, lesser horseshoe (R. hipposideros)	Europe to Asia Minor, north-	15	15			2.23	1.80	0.80
		western India to Sudan							
13	Bat, Keen (Myotis keenii)	Eastern U.S.A., British	21.5	22.7		140-168	0.85		
		Columbia							
14	Bat, long-eared (Plecotus auritus)	Europe to Japan, eastern	0				0.037		
15		Siberia to Sudan	5	6.5			0.069	0.049^3	0.71
16			10	10.7			0.094	0.079^3	0.84
17	Bat, large mouse-eared (Myotis myotis)	Europe to China to Afghan-	1.7				0.020	0.009	
18		istan	2.5				0.051	0.033	0.65
19	Bat, noctule (Nyctalus noctula)	Europe to Siberia, Japan	4.3				0.51	0.38^3	0.75
20		to Palestine	12.5				3.49^5	2.58^3	0.74
21			20				0.403^3	0.314	0.78
22			30				0.682^3	0.484	0.71
23	Bat, parti-colored (Vespertilio murinus)	Europe to Japan, north-	0				0.037		
24		western India	7.05	7.05	50-55				
25			8				0.020		
26	Pipistrelle (Pipistrellus pipistrellus)	Europe to North Asia, Japan	5	5			0.247	0.175^3	0.71
27			5				0.053	0.038^3	0.72
	Rodentia								
28	Dormouse, common (Muscardinus	Southern Italy to England	6			9-10			
29	avellanarius)	and Sweden	10.1				0.80	0.57^3	0.71
30			11.6		10-12				
31	Dormouse, fat (Myoxus glis)	Central and southern Europe	6				0.029	0.021^3	0.72
32			11.8				0.024		
33	Hamster, golden (Mesocricetus auratus)	Rumania, eastern Asia Minor,	5	5-6			0.183	0.132^3	0.72
34		Syria, Palestine, north-	5.5	5.5^6			0.032		
35		western Iran	5.8	6.4^6			0.06		
36			5	5	4-15		0.060-0.080		
37	Marmot, European (Marmota marmota)	Alps	10	10.5		0.35^4	0.018	0.012	0.68
38	Squirrel, arctic ground (Citellus	Northeastern Siberia, Alaska,		5.2	68^7	10			
39	undulatus)	northern Canada	5.9	5.9		6			
40	Squirrel, thirteen-lined ground	Central U.S.A., Canada		$3\text{-}10^6$	5-20		0.081-0.191		
41	(C. tridecimlineatus)		4.0	5.7		1	0.081		
42			8.6	10.2		1.6	0.125		
43			12.5	13.6		1.8	0.197		
44	Suslik (Citellus citellus)	Central Asia, southern		6			0.320	0.230^3	0.72
45		Russia to Austria	7	7.2			0.015		
46			11	11.7		5			
47			13	15.5			0.034		
48	Woodchuck (Marmota monax)	Eastern U.S.A., Canada,		4-7	4-5		0.008-0.034		
49		Alaska	8	8		6			
	Carnivora								
50	Bear, black (Ursus americanus)[8]	North America, north of	-3.5	31.2					
51		Mexico	4.4	35.5		2-3			
	Aves								
52	Hummingbird, Allen's (Selasphorus	U.S.A. (California)	16	21.5					
53	sasin)		22				1.24		
54	Hummingbird, Anna (Calypte anna)	U.S.A. (California)	24				0.84		
55	Swift, European (Micropus apus)		19	23^9		$8\text{-}10^4$	0.7	0.31	
56	Poorwill (Phalaenoptilus nuttalli)	Western U.S.A., Mexico	17.5	19.8					
	Reptilia								
57	Lizard, horned (Phrynosoma cornutum)	U.S.A. (Kansas to Texas),	$4\text{-}6^{10}$				0.051	0.022	
58		northern Mexico to Colorado	$0\text{-}20^{11}$				0.043	0.033	0.73
	Amphibia								
59	Frog (Rana esculenta)		0	1			0.043	0.059	
60			6.1	6.4			0.342	0.449	

/1/ Milliliters per gram of body weight per hour. /2/ Respiratory quotient. Probably does not reflect actual exchange of gases or the true nature of combustion of foods during hibernation. /3/ Calculated. /4/ Respiration rates are very irregular in deep hibernation and there may be several minutes with no respiration followed by several respirations. Cheyne-Stokes respiration is not uncommon; range is average of several minutes. /5/ During awakening from hibernation. /6/ Oral temperature. /7/ Feeble heart beat in deep hibernation, becoming more evident as awakening progresses. /8/ Not a true hibernator, as indicated by the discrepancy between rectal and ambient temperature. /9/ Proventriculus temperature, taken orally. /10/ Body temperature in reptiles and amphibians presumably at or near ambient temperature. /11/ Range is result of long duration of experiments.

313. DIAPAUSE: INSECTS AND MITES

Diapause may be defined generally as a stoppage or radical decline of growth or physiological processes, usually for purposes of enduring extremes of such environmental factors as temperature and humidity. The degree to which purely physiological factors induce diapause cannot be stated with accuracy, if at all. There is no complete agreement on the nature or scope of the phenomenon, nor even whether it be a single phenomenon described inter- or intra-specifically.

	Species	Dormant Stage[1]	Type of Diapause[2]	Observed Characteristics[3]
	Acarina			
1	Metatetranychus ulmi	E-1	F	abcd
2	Tetranychus telarius	A	F	acd
	Coleoptera			
3	Anatolica eremita	A	?	di
4	Dytiscus marginalis	A	O	g
5	Epilachna corrupta	A	F	
6	Leptinotarsa decemlineata	A	F	cdgi
	Diptera			
7	Epistrophe balteata	A	F	
8	E. bifasciata	L- 2	O	di
9	Lucilia sericata	L-2	F	d
10	Sitodiplosis mosellana	L- 2	O	
	Hemiptera			
11	Eurydema ornatum	A	F	ad
12	Eurygaster integriceps	A	O	
13	Psylla pyri	A	F	acd
14	Redvivia persunatus	L-1 to L-2	F	ad
	Hymenoptera			
15	Apanteles glomeratus	PP	F	c
16	Cephus cinctus	PP	O	de
17	Exeristes roborator	L-2	F	d
18	Gilpinia polytoma	PP	O	d
19	Scelphron caementarium	L-2	?	i
20	Spalangia drosophilae	L- 2	F	a
21	Trichogramma cacoeciae	L-2	?	
	Neuroptera			
22	Sialis lutaria	L-2	?	f
	Lepidoptera			
23	Acronicta rumicis	P	F	ac
24	Aisophila pometaria	E	O	d
25	Antheraea pernyi	P	F	cde
26	Aporia crataegi	L-1	O	d
27	Araschnia levana	P	F	c
28	Bombyx mori bivoltine races	E-1	F	acdhi
29	univoltine races	E-1	O	acdhi
30	Chorizabrotis auxiliaris	A	O	dk
31	Cydia pomonella	L-2	F	acd
32	Dendrolimus pini	L-1 to L-2	F	c
33	Dotaterasix oleracea	P	F	acd
34	Eupractis chrysorrhoea	L-1	F	c
35	Graphiolitha molesta	L-2	F	acd
36	Harrisina brillians	P	F	c
37	Loxostege sticticalis	L-2	F	
38	Lymantria dispar	E-2	O	d
39	Malacosoma disstria	E-2	O	
40	Mamestra brassicae	P	F	acd
41	Operophtera brumata	P	O	d
42	Philosamia cynthia	P	F	dei
43	Pieris brassicae	P	F	acd
44	Platysamia cecropia	P	O	dei;
45	Polychrosis botrana	P	F	c
46	Pyrausta nubilalis bivoltine race	L-2	F	ad
47	univoltine race	L-2	O	ad
48	Telea polyphemus	P	?	adei
	Odonata			
49	Anax imperator	L-2	F	c
	Orthoptera			
50	Austroicetes cruciata	E-1	O	d
51	Dociostaurus maroccanus	E-1	O	d
52	Gryllulus commodus	E-1	O	d
53	Gryllus campestris	L-2	?	e
54	Locusta migratoria gallica	E-1	O	d
55	Locustana pardalina	E-1	?	d
56	Melanoplus bivittatus	E-2	O	d
57	M. differentialis[4]	E-1	O	di

/1/ A = adult; E = egg; E-1 = embryo small or half-grown; E-2 = embryo fully grown and nearly ready to hatch; L-1 = larva at close of early or intermediate instar; L-2 = larva at close of final or penultimate instar; P= pupa; PP= prepupa. /2/ F = facultative; O = obligate. /3/ a = dormant diapause terminated by adequate exposure to a specific (often rather low) temperature range; e = failure of brain responsible for growth arrest in larvae and pupae; f = failure of prothoracic gland hormones responsible for growth arrest in larvae and pupae; g = corpus allatum involved in reproductive diapause of adult; h = egg diapause elicited when maternal blood contains secretion from subesophageal ganglion; i = diapause usually accompanied by striking fall in metabolic rate; j = metabolic rate decrease mediated by enzymatic processes, particularly in disappearance of cytochrome-c from tissues; k = diapause termination affected by rising humidity. /4/ Example of species in which diapause does not necessarily occur in all individuals. By selection over several generations, 100% non-diapausing or 100% long-diapausing embryos may be obtained.

314. PHYSIOLOGICAL CHANGES IN SLEEP: MAN

Data are intended to reflect changes caused by sleep alone as opposed to changes caused by rest, relaxation, or recumbency. Entries designated by "no change" are not to be construed to contraindicate profound changes sometimes found from the daytime active state to the relaxed horizontal state. ↑ = Increase; ↓ = Decrease.

	Function or Property	Change in Sleep or Night/Day Ratio(N/D)
1	Calcium, total, serum	No change; ↓ with rest
2	Chloride, serum	No change
3	CO_2, combining power	No change or ↓
4	Creatinine, plasma	No change
5	Eosinophil count	↓
6	Glucose	No change
7	Hematocrit	No change; ↑ with rest
8	Hemoglobin	No change; ↑ with rest
9	pH	No change
10	O_2, arterio-venous difference	No change
11	Phosphorus, inorganic	↓
12	Potassium, serum	No change
13	Protein, plasma	No change; ↑ with rest
14	Sodium, serum	No change
15	Volume, plasma	No change; ↓ with rest
16	Blood pressure, systolic	↓ 15-30 mm Hg
17	Blood pressure, diastolic	↓ 5-10 mm Hg
18	Cardiac output	↓
19	Heart rate	↓
20	Pulse pressure	↓ 10 mm Hg
21	Vessels of extremities	Dilate
22	Gastric acidity, total	↓ 74 ml N/10 NaOH equiv.
23	Gastric acidity, free HCl	↓ 59 ml N/10 NaOH equiv.[1]
24	Gastric motility	↓
25	Saliva, pH	↓ to 6.3
26	Ammonium excretion, rate	↓
27	Bicarbonate excretion, rate	↓
28	Calcium excretion, rate	No change or ↓
29	Chloride excretion, rate	N/D: 0.1-0.16
30	Creatinine excretion, rate	No change
31	Effective renal plasma flow	No change
32	H_2O, tubular reabsorption	N/D: 1.4
33	17-Ketosteroid excretion	N/D: 0.7
34	Nitrogen, amino acid excretion	↓
35	Nitrogen, total excretion	No change, or↓
36	Phosphate excretion	↓
37	Phosphate excretion, fasting state	↑
38	Potassium excretion	N/D: 0.25-0.5
39	Purine body excretion	↓
40	Sodium excretion	N/D:0.14-0.72
41	Specific gravity, urine	↓
42	Titratable acidity	↓
43	Urea excretion	No change
44	Uric acid excretion	↓
45	Urine flow	N/D: 0.5-0.83
46	Urogenin, urine	N/D: 0.7
47	Metabolic rate[2]	No change or ↑10%
48	Babinski sign	Positive
49	Knee jerk	↑ or abolished[3]
50	Pupillary light reflex	↓
51	Time spent in movements	↑; 20-43 sec/hr
52	Number of major movements	↓ 11-28/night
53	Cerebral blood flow	N/D: 1.08[4]
54	Electroencephalogram	Delta waves appear[5]
55	Intracranial pressure	↑
56	Temp., cortical and hypothalmic	↓
57	Respiration rate	No change, ↑or ↓
58	Respiratory rhythm, light sleep	Irregular
59	Respiratory rhythm, deep sleep	Regular
60	Ventilation	↓ to 4.5 L/min

/1/ Almost none present, also reported. /2/ Slight decrease in body temperature also occurs. /3/ Similar response during relaxation. /4/ Calculated. /5/ Also, alpha waves eventually disappear.

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

	Activity	Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
	Men						
1	Supine, basal	82				1.17	
2	Supine, basal	5	15	19-25		1.19	
3	Lying, at ease	5	15	19-25		1.5	28
4	Sitting at ease	5	5	19-25		1.8	54
5	Sitting, calculating	5	7	19-25		1.78	52
6	Sitting, writing	4	4	19-25		1.91	63
7	Sitting, reading	2	2	19-25		1.98	69
8	Standing, at ease	5	8	19-25		1.98	69
9	Standing, relaxed	2	47			1.25	7
10	Dressing	9		18-20	69	4.0	242
11	Brushing clothes	1	3	28		2.57	120
12	Washing hands, face, neck; brushing hair	1	3	28		2.74	134
13	Cleaning shoes	2	2	19-25		3.49	198
14	Dressing, washing, shaving	5	8	19-25		3.56	204
15	Walking (indoors), 2.4 mi/hr	4	4	19-25		4.3	268
16	Walking (indoors), 3.0 mi/hr	4	6	19-25		5.1	336
17	Walking (outdoors), 4.0 mi/hr	1	1	19-25		8.2	601
18	Walking (outdoors), 4.2 mi/hr	4	5	19-25		9.1	678
19	Walking (outdoors), 4.4 mi/hr	4	8	19-25		9.5	712
20	Walking (outdoors), 4.6 mi/hr	3	4	19-25		9.9	746
21	Walking (outdoors), 4.8 mi/hr	5	6	19-25		10.7	815
22	Walking up and down stairs, 97/min	5	10	19-25		8.4	618
23	Walking up and down stairs, 114/min	5	5	19-25		9.3	695
24	Climbing 15 cm stairs, 14.8 m/min				75	9.8	736
25	Climbing 15 cm stairs, 17.6 m/min				75	10.3	780
26	Climbing ladder, 17 cm step, 90° angle, 9.1 m/min					7.7	558
	With 50 lb					14.3	1122
28	Climbing ladder, 17 cm step, 90° angle, 11.9 m/min					11.5	883
	With 50 lb					25.4	2071
30	Walking, hard snow, 6 km/hr	1			83	11.9	917
31	Walking, loose snow, 20 kg load, 4 km/hr	1			83	20.2	1627
32	Walking, snow shoes, soft snow, 4 km/hr	1			83	13.8	1080
33	Skiing, level hard snow, 6 km/hr	1			83	9.9	746
34	Driving car	3	19		64	2.8	139
35	Driving motor cycle	3	19		64	3.4	191
36	Bicycling, 5.5 mi/hr	1			71	4.5	285
37	Bicycling, 9.4 mi/hr	1			71	7.0	498
38	Bicycling, 13.1 mi/hr	1			71	11.1	849
39	Rowing, 33 strokes per minute	5	7			19.0	1524
40	Rowing, 22 strokes per minute	2	2			12.3	951
41	Peeling potatoes	1	1	19-25		2.7	131
42	Laboratory work	5	5	19-25		3.2	174
43	Washing dishes	3	3	19-25		3.3	182
44	Making beds	1	1	19-25		7.0	498
45	Cleaning windows	10		27	61	3.7	216
46	Copper tooling (sitting)	2	2	41		1.8	54
47	Hand loom weaving (sitting)	1	1	40		1.9	62
48	Chip carving (reclining)	1	2	40		2.0	71
49	Miscellaneous office work, sitting	10	36		55-72	1.6	37
50	Miscellaneous office work, standing	10	45		55-72	1.8	55
51	Shoemaking, shoe repair	6	17			2.7	131
52	Shoemaking, shoe manufacturing	4	16			3.0	156
53	Locksmith, working	1	5	19	53	2.5	114
54	Tailor, cutting	2		21	63	2.6	122
55	Tailor, pressing	2				3.9	233
56	Armature winding	2	8			2.2	88
57	Radio mechanics	4	8			2.7	131
58	Printing, hand compositor	1	1			2.2	88
59	Printing, printer	1	1			2.2	88
60	Watch and clock repairer trainee		8			1.6	37
61	Light assembly line		3			1.8	54
62	Draftsman		5			1.8	54
63	Light machine work (engineering)		8			2.4	105
64	Typewriter mechanic trainee		6			2.1	80
65	Medium assembly work		14			2.7	131
66	Sheet metal worker		8			3.0	156
67	Machinists (engineering)		12			3.1	165
68	Plastic moulding		9			3.3	182
69	Joiners		18			3.6	208
70	Turners		4			3.7	216
71	Tool room workers		4			3.9	233
72	Machine fitting		12			4.2	259
73	Casting lead balls in mould		2			4.8	310
74	Loading chemicals into mixer		2			6.0	413
75	Unloading battery boxes from oven		4			6.8	481
76	Shoveling, 8 kg load, 1 m lift, 12/min					7.5	541
77	Hewing with pick					7.0	498
78	Pushing wheelbarrow, 57 kg load, 4.5 km/hr					5.0	327
79	Bricklaying					4.0	242
80	Mixing cement					4.7	302
81	Stonemasonary, shaping stones					3.8	225
82	Plaster lathing					3.1	165
83	Plastering walls					4.1	250
84	Carpentry, measuring wood	1	35		62	2.4	105

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

	Activity	Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
	Men (concluded)						
85	Carpentry, machine sawing	1	35		62	2.4	105
86	Carpentry, joining floorboards	1	35		62	4.4	276
87	Carpentry, chiselling	1	31		65	5.7	387
88	Carpentry, sawing soft wood	1	31		65	6.3	439
89	Carpentry, drilling hard wood	1	35		62	7.0	498
90	Carpentry, sawing hard wood	1	31		65	7.5	541
91	Carpentry, planing soft wood	1	31		65	8.1	592
92	Carpentry, planing hard wood	1	31		65	9.1	678
93	Farming, mowing with horse drawn reaper	15		15-55		4.3	268
94	Farming, threshing, throwing sheaves to thresher	7		15-41		5.6	379
95	Farming, hoeing, deep ridging	5	13	24-36	57	9.5	712
96	Farming, hoeing		12			4.4	276
97	Farming, hand milking	1		28	64	4.7	302
98	Farming, machine milking	1		28	64	3.7	216
99	Farming, horse ploughing	7	16	18-39	57-86	5.9	404
100	Farming, tractor ploughing	7	22	18-39	57-86	4.2	259
101	Lumbering, tree felling	11				10.7	815
102	Lumbering, tree trimming	11				10.2	772
103	Lumbering, tree barking	11				10.1	763
104	Lumbering, crosscutting with bucksaw	11				9.0	669
105	Lumbering, stacking firewood	2				6.3	439
106	Lumbering, chopping, vertical, 1.25 kg ax, 19/min	1		23	82	8.9	490
107	Lumbering, chopping, horizontal, 1.25 kg ax, 34/min	1		23	82	13.2	1028
108	Coal mining, hewing	18				7.0	498
109	Coal mining, loading	20				7.1	507
110	Coal mining, timbering	18				5.7	387
111	Coal mining, drilling	30				5.8	396
112	Coal mining, pushing tubs	12				8.0	584
	Women						
113	Supine, basal	49	265	22	55	.98	
114	Sitting	57	338	22	55	1.09	11
115	Standing	16	47	22	55	1.11	13
116	Dressing and undressing	12		8-12	34	2.3	135
117	Washing, dressing, undressing	3		43-55	70	3.3	237
118	Walking, 2.8 mi/hr	1	3	29		2.00	104
	Walking, 2.8 mi/hr, carrying a 20 lb load						
119	Load carried with shoulder yoke	1	3	29		1.94	98
120	Load carried on one shoulder	1	3	29		2.07	111
121	Load carried in two bundles in either hand	1	3	29		2.19	124
122	Load carried on tray in front of body	1	3	29		2.25	130
123	Load carried on tray in front of body with strap around shoulder	1	3	29		2.28	133
124	Load carried on head	1	3	29		2.49	154
125	Load carried on hip	1	3	29		2.72	1.78
126	Horizontal walking, 1.1 mi/hr	9	60	24		1.99	103
127	Horizontal walking, 2.2 mi/hr	9	64	24		2.84	190
128	Horizontal walking, 3.4 mi/hr	9	51	24		2.90	196
129	Skiing, level hard snow, moderate speed	1			57	10.8	1002
130	Skiing, uphill hard snow, maximum speed	1			68	18.6	1798
131	Washing dishes, top of pan 42 in.from floor (ht of subject 66 in.)	1	3			1.37	40
132	Washing dishes, top of pan 32 in.from floor (ht of subject 66 in.)	1	3			1.53	56
133	Paring potatoes (sitting)	7	24	27		1.23	26
134	Paring potatoes (standing)	7	26	27		1.29	32
135	Beating batter (standing)	7		22		1.43	46
136	Kneading dough (standing)	7		22		2.04	108
137	Step up 7 inches	9	36	26		2.77	183
138	Arm reach and trunk bend to 3 in. above floor (average ht of sub. 62 in.)	9	36	26		2.88	194
139	Arm reach and knee bend to 3 in. above floor (average ht of sub. 62 in.)	7	28	26		4.12	320
140	Arm reach and body pivot 36 in. above floor (average ht. of sub. 62 in.)	9	36	26		1.75	77
141	Arm reach 72 in. above floor (average ht of subjects 62 in.)	9	36	26		1.82	86
142	Hand sewing sheets, 18 stitches/min	1	5			1.18	20
143	Hand sewing sheets, 30 stitches/min	1	6			1.25	28
144	Darning	1	2	22		1.26	29
145	Crocheting, 32 stitches/min	1	5	22		1.27	30
146	Knitting, 23 stitches/min	1	4	22		1.29	31
147	Machine sewing (foot-operated)	1	8			1.43	46
148	Washing clothes, by hand	7	25	22		2.69	175
149	Rinsing clothes	7	21	22		2.42	147
150	Drying clothes (in extractor)	7	21	22		2.08	112
151	Wringing clothes, by hand	7	23	22		2.21	125
152	Putting up and removing clothes line	2	7	23		2.14	118
153	Hanging up clothes from basket on the floor	7	21	22		2.63	168
154	Ironing, standing (high board)	7	7	22		1.64	67
155	Ironing, standing (normal board)	7	7	22		1.69	72
156	Washing floor (on knees)	1	3	22		1.63	66
157	Sweeping floor	1	4	22		1.85	89
158	Vacuum-cleaning rug (moving 1 ft per sec)	1	10			1.63	66
159	Vacuum cleaning rug (moving 3 ft per sec)	1	12			2.58	163
160	Bedmaking, stripping	1		55	80	5.4	451
161	Typing, electric, 40 words per min	6	7		45-52	1.31	34
162	Typing, mechanical, 40 words per min	6			45-52	1.48	51
163	Typing, 59 words per min	1	4	18		1.34	37
164	Typing, 115 words per min	1	3	31		1.72	76
165	Leather tooling (reclining)	3	3	36		1.13	15
166	Leather tooling (sitting)	16	41	20		1.28	31
167	Leather stamping (sitting)	14	38	20		1.33	36

315. ENERGY COST, WORK: MAN (Concluded)

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

	Activity	Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
	Women (concluded)						
168	Leather carving (sitting)	11	44	23		1.65	68
169	Leather lacing (sitting)	12	27	22		1.39	42
170	Copper tooling (sitting)	3	3	29		1.39	42
171	Chip carving (sitting)	17	53	22		1.61	64
172	Hand loom weaving	3	3	29		1.58	61
173	Table loom weaving	17	47	22		1.69	72
174	Floor loom weaving	3	4	42		2.12	116
175	Chisel carving, hardwood (sitting)	5	5	32		2.14	118
176	Chisel carving, softwood (sitting)	5	5	33		2.16	120
177	Printing (floor press, standing)	5	26	22		2.31	136
178	Hand sawing (standing)	16	47	22		3.27	234
179	Turning and finishing	8	36	19-33	47-65	3.0	206
180	Forging	4	20	22-32	55-69	3.1	216
181	Stamping	2	12	35-44	64-55	3.2	227
182	Hoisting shelf with pulley	1	5	54	56	3.3	237
183	Tool setting	5	25	21-26	45-59	3.4	247
184	Gauging	4	19	18-44	52-55	4.0	308
185	Laboring (general industrial)	5	14	35-51	44-86	5.1	420

316. ENERGY COST, PROGRESSION: MAN

Values for speed are kilometers per hour, unless otherwise indicated. Those for Calories are calculated on assumption that one liter of excess oxygen = 5.05 Calories, and that the resting level (included in the values) = 0.3 liters/min (1.46 Calories)[1].

	Progression	Subject	Speed km/hr	Energy Cost Cal/min	Energy Cost LO_2/min
1	Walking, horizontal,	Normal,	4	3.5-4.5	0.7-0.9
2	treadmill	75 kg	6	5.0-5.5	1.0-1.1
3			8	9.0-10.1	1.8-1.9
4			10	14.6-17.6	2.9-3.5
5		Athlete,	8	8.0	1.6
6		63 kg	10	11.6	2.3
7			12	16.1	3.2
8	Walking, grade, 0%	Normal,	4.2	4.0-4.5	0.8-0.9
9	treadmill, +5%	70-79 kg		5.5-6.0	1.1-1.2
10	uphill +10%			7.5-8.0	1.5-1.6
11	+15%			10.0-10.5	2.0-2.1
12	+20%			12.6-13.1	2.5-2.6
13	+25%			15.1-16.1	3.0-3.2
14	downhill -5%	Normal,	4.2	3.5-4.0	0.7-0.8
15	-10%	70-79 kg		3.5	0.7
16	-15%			3.5	0.7
17	-20%			4.0-4.5	0.8-0.9
18	-25%			5.0	1.0
	Walking, horizontal,				
19	hard surface road	68-69 kg plus	5.5	5.5	1.1
20	grass covered road	9 kg clothing	5.6	6.5	1.3
21	furrow in field	and apparatus	5.4	7.0	1.4
22	harvested field		5.2	7.0	1.4
23	plowed field		5.3	8.0	1.6
24	harrowed field		5.1	10.5	2.1
25	hard snow	83 kg	6.0	11.9	2.3
			9.1	16.1	3.2
27	soft snow	83 + 20 kg[2]	3.9	20.7	4.1
28	Running, horizontal,	74 kg	12	15.1-16.1	3.0-3.2
29	treadmill; values		14	17.6-18.7	3.5-3.7
30	for Cal. and O_2 are		16	20.2-21.7	4.0-4.3
31	for work and		18	24.2-25.8	4.8-5.1
32	recovery		20	30.3-34.3	6.0-6.8
33	Running, horizontal,	75 kg	19.2	28-31	5.5-6.1
34	on track; values for	74 kg	26.3	66-91	13-18
35	Cal. and O_2 are for	70 kg	28.1	76-167	15-33
36	work and recovery	72 kg	28.8	106-232	21-46
37	Running, grade 8.6%	70 kg	9.3	13.1	2.6
38			11.3	16.2	3.2

	Progression	Subject	Speed km/hr	Energy Cost Cal/min	Energy Cost LO_2/min
39	Carrying 20 kg load				
40	Walking, horizontal	70 kg	1.6	3.5	0.7
41			3.2	4.5	0.9
42			4.8	6.0	1.2
43			6.4	9.0	1.8
44	Walking, horizontal,		8.0	14.1	2.8
45	Walking, grade 36%		0.8	6.0	1.2
46			2.4	15.6	3.1
47	Bicycling, level	70 kg + cycle	8.9	3.0	0.6
48		and gas-meter = 21 kg	15.1	6.0	1.2
			21.3	10.0	2.0
	Bicycling, grade[3]				
49	Free-wheeling, DH	79 kg + cycle	8.6	2.5	0.5
50	Cycling, DH, -2%	and gas-		2.5	0.5
51	DH, -10%	meter = 16 kg		4.0	0.8
52	UH, +2%			6.0	1.2
53	UH, +10%			17.6	3.5
	Swimming				
54	Breast stroke,	Excellent	16 m/min	7.0	1.4
55	steady state	swimmer	32	10.0	2.0
56			44	14.6	2.9
57			56	20.2	4.0
58	short sprint,	Good	60	39[3]	7.8[3]
59	20-40 m	swimmer	72	72[3]	14.3[3]
60	Crawl, steady	Excellent	36	10	1.9
61	state	swimmer	58	17	3.3
62	short sprint,	Good	60	23[3]	4.5[3]
63	20-40 m	swimmer	80	45[3]	9.0[3]
64			104	124[3]	24.5[3]
65	Skiing, horizontal,	83 kg	4.16	8.5	1.7
66	loose snow,		10.67	15.6	3.1
67	steady state		14.73	26.2	5.2
68		Carrying 20 kg	4	13.1	2.6
69	Snow-shoeing, horiz.		4	14.1	2.8
70		Carrying 20 kg	4	15.6	3.1
71	Rowing, assistant	70 kg	3.2	5.0	1.0
72	also in boat		5.6	10.0	2.0
73	Skating, smooth ice	70 kg	14.5	8.0	1.6
74			20.9	13.5	2.7

/1/ At the resting level or for light work a satisfactory conversion factor is one liter of oxygen = 4.9 Calories, but work requiring 1.5-2 liters of oxygen per minute will use glycogen, and a factor of one liter O_2 = 5.05 Calories is considered more valid. /2/ Extra load carried. /3/ Work plus recovery.

Part I. MAMMALS

	Species	Velocity mi/hr	Remarks		Species	Velocity mi/hr	Remarks
			Running				
1	Antelope, prong-horned (Antilocapra americana)	70	Maximum in short burst.	24	Hare, arctic (Lepus groenlandicus)	30-40	Pressed, 3 miles.
2		20-36	Normal gait.	25	Horse, domestic (Equus caballus)	42.3	Running, 440 yards.
3	Ass, Asiatic wild (Equus hemionus)	30	Average, 16 miles.	26		39.1	Running, 1 mile.
4	Bison, American (Bison bison)	30-32	Maximum, pressed.	27		31.1	Trotting, 1 mile.
5	Camel, dromedary (Camelus dromedarius)	9-10	Racing, 115 miles in 12 hr.	28		11.2	Trotting, 100 miles.
6		2	Normal walking, loaded.	29	Kangaroo, great (Macropus sp)	25	Chased.
7	Caribou, barren ground (Rangifer arcticus)	25+	Average maximum.	30	Mink (Mustela vison)	7-8	Average maximum.
8	Cheetah (Acinonyx jubatus)	65-70	Maximum, 440 yards.	31	Mole, common (Scalopus aquaticus)	1.5	On surface.
9	Chipmunk, least (Eutamias sp)	10	Pressed, 50 yards.	32	Monkey, langur (Presbytis entellus)	23+	On ground, 70 yards.
10	Coyote (Canis latrans)	28-43	Maximum, short dash.	33	Moose (Alces americana)	35	Pressed to maximum, 1/4 mile.
11		24	Average, 1 mile.	34	Rabbit, white-tailed jack (Lepus townsendii)	34	50 yards.
12	Deer, white-tailed (Odocoileus virginianus)	49	Maximum, pressed.	35	Rat, Calif. kangaroo (Dipodomys heermanni)	5, 4-12	Pressed, 16-52 feet.
13		15-18	Not pressed.	36	Reindeer (Rangifer tarandus)	13.3	Pulling sled, 1.6 miles.
14	Dog, domestic (Canis familiaris)	43	Maximum for saluki.	37	Rhinoceros, black (Diceros bicornis)	20+	Sustained maximum.
15		30-36	Racing greyhound, average	38	Sheep, bighorn (Ovis canadensis)	30	Pressed, 1/4 mile.
16		22	Average, 1 mile, foxhound.	39	Sloth	0.5	
17	Elephant, African (Loxodonta africana)	25	Charging, 120 yards.	40	Squirrel, gray (Sciurus carolinensis)	15	40 or 50 feet.
18	Elk, American (Cervus canadensis)	18	Unhurried, 1 mile.	41	Squirrel, southern flying (Glaucomys volans)	4-5	Maximum.
19	Fox, gray (Urocyon cinereoargenteus)	40	Pressed, 3/4 mile.	42	Swine, domestic (Sus scrofa)	11	
20	Fox, red (Vulpes fulva)	26	Average maximum, 1 mile.	43	Warthog (Phacochoerus aethiopicus)	30	
21	Gazelle, Grant's (Gazella granti)	50+	1/2 mile.	44	Wildebeest (Connochaetes sp)	50+	Maximum, 1/4 mile.
22	Giraffe (Giraffa camelopardalis)	28-32	Pressed.	45	Wolf (Canis lupus)	28-40	Maximum up to 200 yards.
23	Goat, mountain (Oreamnos americanus)	20+	Maximum.	46	Woodchuck (Marmota monax)	10	Maximum, 1 minute.
	Species	Distance ft	Remarks		Species	Distance ft	Remarks
			Leaping, Horizontal				
47	Antelope, pronghorned (Antilocapra americana)	12-20	Bound at high speed.	58	Mink (Mustela vison)	0.8-1.2	Normal bound.
48	Chipmunk (Tamias striatus)	6	Maximum.	59	Mouse, woodland jumping (Napaeozapus insignis)	10-12	Frightened, maximum leap.
49	Deer, mule (Odocoileus hemionus)	18-25	Effortless bounding.	60		1-3	Normal leap.
50	Dog, domestic (Canis familiaris)	15	Stride, racing whippet.	61	Puma (Felis concolor)	40-47?	Maximum leap.
51	Fisher (Martes pennanti)	40	Descending diagonally.	62	Rabbit, white-tailed jack (Lepus townsendii)	18-21	Maximum bound
52	Hare, varying (Lepus americanus)	4-10	Normal bounds.	63		6-9	Slow speed hop.
53	Impala (Aepyceros melampus)	30-40	Estimated maximum.	64	Rat, kangaroo (Dipodomys sp)	9-12	Frightened, maximum leap.
54	Jerboa (Dipus sagitta)	12-15	Estimated maximum.	65	Squirrel, southern flying (Glaucomys volans)	152	Max. diagonal descending glide.
55	Kangaroo, great (Macropus sp)	35	Chased, maximum leap.	66	Squirrel, red (Tamiasciurus hudsonicus)	15-20	Max. diagonal descending leap.
56	Lynx, Canadian (Lynx canadensis)	12-15	Normal maximum leap.	67	Squirrel, gray (Sciurus carolinensis)	2	Normal bound.
57	Marten, American (Martes americana)	3	Normal maximum bound.	68	Weasel, long-tailed (Mustela frenata)	2.5-3.5	Average maximum bound.
			Leaping, Vertical				
69	Antelope, pronghorned (Antilocapra americana)	5		77	Mouse, meadow jumping (Zapus hudsonius)	3+	
70	Coyote (Canis latrans)	4	"Spy-hop."	78	Mouse, kangaroo (Microdipodops megacephalus)	1.5	
71	Deer, white-tailed (Odocoileus virginianus)	8	Pressed.	79	Muskrat (Ondatra zibethicus)	2.5	
72	Elk, American (Cervus canadensis)	8	Pressed.	80	Peccary (Tayassu sp)	4	
73	Impala (Aepyceros melampus)	8	Estimated maximum.	81	Puma (Felis concolor)	10-18?	
74	Jerboa (Dipus sagitta)	3+		82	Rabbit, antelope jack (Lepus alleni)	2.5-5.5	Easy bound.
75	Kangaroo, giant (Macropus sp)	9		83	Rat, large kangaroo (Dipodomys spectabilis)	1.5-2	"Spy-hop."
76	Kangaroo, rat (Bettongia penicillata)	3		84	Squirrel, red (Tamiasciurus hudsonicus)	3	
	Species	Velocity mi/hr	Remarks		Species	Velocity mi/hr	Remarks
			Swimming				
85	Beaver, American (Castor canadensis)	2	Maximum.	90	Mink (Mustela vison)	1-1.5	Normal.
86	Caribou, woodland (Rangifer caribou)	6	Estimated maximum.	91	Mole, common (Scalopus aquaticus)	0.7	
87	Deer, white-tailed (Odocoileus virginianus)	4±	Estimated maximum.	92	Muskrat (Ondatra zibethicus)	3	Maximum.
88	Dolphin	35-37+	Playing before ship.	93	Porcupine (Erethizon dorsatum)	2±	Cruising.
89	Dolphin, bottle-nosed (Tursiops truncatus)	21	Maximum.	94	Whale, blue (Sibbaldius musculus)	16	Chased.
			Flying				
95	Bat	20					

	Species	Velocity mi/hr	Remarks[1]
	Birds: Flying		
1	Blackbird, tricolored (Agelaius tricolor)	46-48	To and from nest.
2	Bluebird, mountain (Sialia currucoides)	18	Side wind.
3	Bobwhite (Colinus virginianus)	28-49	Normal to frightened.
4	Bunting, yellow (Emberiza citrinella)	26-35	Easy flight.
5	Canvasback (Aythya valisineria)	72‡	Air speed, pressed.
6	Catbird (Dumetella carolinensis)	12-16	
7	Crane, sandhill (Grus canadensis)	31-35	Headwind to calm.
8	Crow, American (Corvus brachyrhynchos)	17-35	
9	Cuckoo, European (Cuculus canorus)	27	Pressing some.
10	Curlew, long-billed (Numenius americanus)	35-55	Normal to maximum, pressed.
11	Dove, ring (Columba palumbus)	27-51	Easy flight to pressing hard.
12	Eagle, golden (Aquila chrysaetos)	28-120	Migrating to diving.
13	Egret, American (Casmerodius albus e.)	17-32	Normal to pressed.
14	Falcon, peregrine (Falco peregrinus)	26-180	Cruising to diving.
15	Flicker, red-shafted (Colaptes cafer)	25-44	Normal to alarmed.
16	Gannet (Moris bassana)	25-48	
17	Goldfinch, European (Carduelis carduelis)	26	Normal.
18	Goose, Canada (Branta canadensis m.)	20-60	Cruising to pressed (air speed).
19	Grackle, bronzed (Quiscalis versicolor)	20-30	
20	Grouse, ruffed (Bonasa umbellus)	30-51	Flying in brush and to cover.
21	Gull, herring (Larus argentatus)	12-36	Easy flight.
22	Harrier, American marsh (Circus cyaneus)	21-38	Migrating, 2/3 mile.
23	Hawk, Cooper's (Accipiter cooperi)	21-55	Migrating, 2/3 mile.
24	Heron, great blue (Ardea herodias)	18-36	Cruising to pressed.
25	Hummingbird, ruby-throated (Archilochus colubris)	45-55	Easy flight.
26	Ibis, white-faced glossy (Plegadis guarauna)	30-33	Cruising.
27	Jay, blue (Cyanocitta cristata)	20	
28	Kestrel (Falco tinnunculus)	35-44	Easy flight.
29	Killdeer (Charadrius vociferus)	25-55	
30	Kingfisher, belted (Megaceryle alcyon)	36	Easy flight.
31	Lark, horned (Eremophila alpestris)	17-54	
32	Linnet (Carduelis cannabina)	26-36	Short to long flight.
33	Loon, common (Gavia immer)	53	5 miles.
34	Magpie (Pica pica)	19-35	Normal to pressed.
35	Mallard (Anas platyrhynchos)	26-60	Normal to pressed (air speed).
	Birds: Running		
71	Avocet (Recurvirostra americana)	8	Pressed, 50 feet.
72	Chicken, domestic (Gallus gallus)	9	
73	Curlew, long-billed (Numenius americanus)	8-10	75 yards, pressed.
74	Emu (Dromiceius novaehollandiae)	35-40	Not maximum.
75	Grouse, sage (Centrocercus urophasianus)	2	Before car, 30 feet.
76	Killdeer (Charadrius vociferus)	5	30 feet.
	Reptiles: Running		
83	Lizard, six-lined	18	Not pressed, 1 minute.
84	Red racer	3.6	Maximum.
85	Sidewinder	2.0	Maximum.
86	Snake, coral king	0.7	Maximum.
	Fish: Swimming		
87	Carp	0.9	
88	Flying fish, biplane	22-40	Maximum in pre-flight taxi.
89	Mackerel-like fish	30	Cruising.
90	Perch	1.3	
91	Pike	10	
92	Salmon	7	

	Species	Velocity mi/hr	Remarks[1]
36	Martin, house (Chelidon urbica)	24-27	Cruising.
37	Meadowlark, western (Sturnella neglecta)	26-40	
38	Merganser, American (Mergus merganser a.)	30	1.4 mile, not pressed.
39	Oriole, Bullock's (Icterus bullockii)	28-32	
40	Osprey (Pandion haliaetus)	20-56	Migrating, 2/3 mile.
41	Owl, tawny (Strix aluco)	40-45	Deliberate flight to pressed.
42	Partridge, European (Perdix perdix)	25-35	Normal flight.
43	Pelican, brown (Pelecanus occidentalis)	14-26	Maintain 26 mph for 8 miles.
44	Pheasant, ring-necked (Phasianus colchicus)	27-38	
45	Pigeon, green (Dendrophasa sp)	44-48	2 miles.
46	Pintail (Anas acuta)	49-65‡	Pressed (air speed).
47	Plover, European golden (Pluvialis apricaria)	60-70	Air speed, chased.
48	Quail, California (Lophortyx californica)	38-58	
49	Raven (Corvus corax)	24-40	Normal, to 1300 yards.
50	Redhead (Aythya americana)	31-55	Cruising to pressed.
51	Robin (Turdus migratorius)	17-36	
52	Rook (Corvus frugilegus)	24-45	
53	Sandpiper, western (Ereunetes mauri)	44-55	Level flight to maxium air speed.
54	Shoveller (Spatula clypeata)	25-53+	
55	Shrike (Lanius ludovicianus)	22-45	
56	Sparrow, house (Passer domesticus)	24-35	
57	Starling, European (Sturnus vulgaris)	18-51	Calm to pressed.
58	Stork, white (Ciconia ciconia)	48	Migrating, air speed.
59	Swallow, barn (Hirundo rustica)	20-46	
60	Swan, whistling (Cygnus columbianus)	18-55	Cruising to pressed (air speed).
61	Swift	68+	Passed plane at this air speed.
62	Teal, European (Anas crecca)	44-68	Cruising to pressed (air speed).
63	Tern, common (Sterno hirundo)	13-29	Cruising.
64	Thrasher, sage (Oreoscoptes montanus)	22-29	Cruising.
65	Thrush, song (Turdus philomelus)	31	Pressed.
66	Titmouse, blue (Parus caeruleus)	21	Tree to tree, 40 yards.
67	Turkey, wild (Meleagris gallopavo)	55	Pressed, 1 mile.
68	Vulture, turkey (Cathartes aura)	15-34	Normal to migrating, 2/3 mile.
69	Warbler, willow (Phylloscopus trochilla)	24-27	Pressed.
70	Woodcock (Philohela minor)	5-13	
77	Ostrich (Struthio camelus)	50+	1/2 mile.
78	Partridge, chukor (Alectoris graeca)	12-18	12 mph for 20 yards.
79	Pheasant, ring-necked (Phasianus colchicus)	8-21	30-200 yards.
80	Quail, California (Lophortyx californica)	12-15	Chased.
81	Road runner (Geococcyx californianus)	10-22	Pressed, 50-300 yards.
82	Sparrow, vesper (Pooecetes gramineus)	9	Upgrade, 100 feet.

	Species	Distance ft	Remarks
	Fish: Leaping, Horizontal		
93	Flying fish, biplane (Cypselurus sp)	650-1300	Horizontal glide.
94	Flying fish, biplane (Parexocoetus sp)	7-25	Horizontal glide.
95	Flying fish, monoplane (Exocoetus sp)	33-67	Horizontal glide.
96	Flying fish, primitive (Oxyporhamphus sp)	17-27	Horizontal glide.
	Fish: Leaping, Vertical		
97	Atherine, fresh-water	10-20x[2]	
98	Flying fish, monoplane (Exocoetus sp)	7-13	High point of glide.
99	Mullet, striped	10-20x[2]	
100	Tuna	Several	

/1/ First part of remark covers first figure of range in velocity column, second part of remark covers second figure. /2/ Times length of fish.

318. PHYSICAL TRAINING, EFFECTS: MAN

	Test	Subjects	Changes in Physical Capacity				Test	Subjects	Physiological Effects			
			Training		Gain				Training		Gain	
			Before	After	%				Before	After	%	
1	Pushups, max. no.	Men	18,1	21,3	17,6	37	Basal O_2 consumption, ml/m	Men	228	208	9	
2	of times	Women	10,7	15,6	46	38	O_2 cost in running	Men	13,57	14,13	4	
3	Pullups, max. no.	Men	10,0	10,8	8	39	Respiratory efficiency	Men	55,3	46,1	17	
4	of times	Women	5,5	8,7	59	40	Resp. quotient	Men	0,82	0,93		
5	Situps, max. no.	Men	38,4	51,1	34	41	Resp. rate, exercising	Runners[1]	44	48		
6	of times	Women	19,9	32,2	63	42	Resp. min. volume	Men	6,23	5,69	9	
7	Shoulder strength, push, lb	Men	48,7	53,2	9,2	43	Vital capacity	Runners[1]	4,74	4,36		
8	pull, lb	Women	44,6	46,8	5,1	44	Alveolar pCO_2, mmHg	Men	41,5	41,3		
9	Muscular strength	Weight lifters	102,7	107,7	4,6	45	Alveolar pO_2, mmHg	Men	100,3	98,1		
10		Non-lifters	101,5	104,3	2,7	46	Blood gas capacity, vol. % 0_2	Men	19,83	20,18		
11	Knee extension, kg	Trained limb	24,1	30,9	28,2	47	Hemoglobin, g/100ml	Men	14,8	15,2		
12		Untrained limb	24,5	33,6	37,0	48	Red blood cells, millions	Men	4,62	4,73		
13	Hand curl, kg	Trained limb	9,8	12,6	28,2	49	Hematocrit	Men	44,1	46,0		
14		Untrained limb	9,6	11,8	22,6	50	Alkaline reserve, CO_2	Men	47,8	46,6		
15	Finger ergograph,	Trained limb	13,2	26,1	97,4	51	combining power, vol. %	Runners[1]	48,0	48,1		
16	total work, kg	Untrained limb	10,9	16,6	52,7	52	Alk. res, after running, mM/L	Men	11,8	10		
17	Finger ergograph, no. times	Men	276	858	212	53	Exercise pulse rate	Men	151	146		
18	Left arm performance	Right arm trained	53,5	79,8	49,2	54		Runners[1]	134	111		
19		Right arm untrained	53,2	59,2	9,5	55	Pulse after 30 sec recovery	Runners[1]	115	77		
20	Shot put, 8 lb	Weight lifters	33,3	36,3	9,0	56	Resting pulse	Men	66,8	61,8		
21		Non-lifters	31,2	31,6	1,3	57	Resting blood pressure	Men	114/65	113/67		
22	Shot put, 12 lb	Weight lifters	27,2	29,5	8,5	58	Stroke volume, ml	Men	82	80	-2,5	
23		Non-lifters	25,1	25,7	2,4	59	Cardiac output, liters/hr	Men	4,62	4,71	-2	
24	Broad jump, standing, ft	Weight lifters	7,5	7,8	4,0	60	Systolic heart volume, ml	Men	565	469	-17	
25		Non-lifters	7,1	7,1	0	61	Heart diameter, cm	Men	11,9	10,9	-8	
26	Running, 60 yd, sec	Weight lifters	7,9	7,6	3,8	62	Heart volume, ml	Men	785	930		
27		Non-lifters	8,1	8,1	0	63		Women	560	790		
28	Running, 300 yd, sec	Men, 18-22 yr	44, 3	42,7	3,6	64	Blood volume, ml	Men	5250	5580		
29	Running, 5 min, yd	Men	1490	1510	1,3	65		Women	4070	5670		
30	Obstacle course, sec	Men	24,7	22,0	10,9	66	Leukocytes, thousands	Men	5,96	6,1		
31	Muscle endurance	Weight lifters	220,4	267,8	21,0	67	Plasma chloride, mEq	Men	103,6	105,8		
32		Non-lifters	189,5	235,9	24,5	68	Plasma nitrogen, g/L	Men	10,3	10,8		
33	Endurance	Women	25,2	31	23	69	Blood sugar, max., mg/100ml	Men	127	134		
34	Walking efficiency	Men	15,3	16,9	10,4	70	Blood lactate, max., mg/100ml	Men	114	134		
35	Max. work, treadmill, kgM	Men	3786	6046	59,6	71	Blood lactate, exercise[2] 100m	Men	146	192		
36	Work per liter O_2 debt	Men	484	737	52,3	72		Runners[1, 3]	19,1	13,4		

[1] Champion male runners; values before training are not necessarily for those men for whom values are given after training. [2] After strenuous exercise. [3] During mild exercise.

319. PHYSIOLOGICAL CHANGES DURING EXERCISE, EFFECT OF AGE: MAN

Values are results obtained with various age-groups of healthy, well-trained subjects during maximum physiological activity (treadmill) or bicycle). Values in parentheses are estimate "c" of the 95% range (cf. Introduction).

	Specifications		6-6 yr	7-9 yr	10-11 yr	12-13 yr	14-15 yr	16-18 yr	20-33 yr
1	Body height, cm	♂	113, 5(107-128)	135, 0(125-143)	145, 4(132-157)	154, 4(139-169)	171, 8(150-188)	176, 9(165-187)	176, 7(155-188)
2		♀	111, 6(108-114)	132, 0(121-142)	140, 6(129-148)	158, 5(150-175)	164, 9(156-173)	167, 7(162-176)	165, 8(155-175)
3	Body weight, kg	♂	20, 8(16, 0-27, 8)	30, 7(25, 1-36, 5)	36, 5(31, 1-44, 7)	43, 6(31, 8-60, 6)	59, 5(40, 6-76, 2)	64, 1(45, 2-73, 4)	70, 4(61, 7-86, 6)
4		♀	18, 4(17, 4-21, 9)	27, 2(20, 6-33, 0)	32, 5(27, 0-37, 4)	46, 7(39, 6-60, 5)	56, 0(46, 2-67, 1)	57, 3(50, 5-63, 7)	60, 3(50, 0-72, 8)
5	Vital capacity[1], L	♂		2, 21(1, 84-2, 51)	2, 65(2, 24-3, 25)	3, 22(2, 52-4, 33)	4, 55(2, 78-6, 57)	5, 17(3, 20-6, 48)	5, 68(4, 17-7, 26)
6		♀		1, 95(1, 69-2, 24)	2, 30(1, 86-2, 63)	3, 25(2, 52-4, 01)	3, 74(2, 94-4, 32)	4, 14(3, 24-5, 04)	4, 28(3, 15-5, 76)
7	Max. heart rate	♂	203(188-214)	208(191-220)	211(200-227)	205(175-237)	203(178-222)	202(194-210)	197(171-212)
8		♀	204(176-214)	211(194-223)	209(192-220)	207(188-222)	202(192-217)	206(188-214)	198(184-225)
9	Max. O_2 intake[2],	♂	1, 01(0, 77-1, 30)	1, 75(1, 40-2, 01)	2, 04(0, 85-2, 32)	2, 66(1, 79-3, 40)	3, 53(2, 59-4, 47)	3, 66(2, 84-4, 35)	4, 11(3, 30-5, 09)
10	L/min	♀	0, 88(0, 74-0, 94)	1, 50(1, 21-1, 79)	1, 70(1, 48-1, 94)	2, 31(2, 01-2, 72)	2, 58(2, 02-3, 31)	2, 71(2, 25-3, 08)	2, 92(0, 41-3, 40)
11	Max. O_2 intake[2],	♂	49, 1(43, 2-57, 6)	56, 9(51, 8-62, 7)	56, 1(51, 1-61, 5)	56, 5(53, 0-61, 9)	59, 5(56, 8-63, 7)	57, 6(51, 0-62, 4)	58, 6(51, 1-67, 4)
12	ml/min/kg	♀	47, 9(42, 4-52, 2)	55, 1(49, 3-58, 8)	52, 4(46, 4-56, 1)	49, 8(45, 0-53, 5)	46, 0(42, 5-52, 5)	47, 2(42, 8-51, 2)	48, 4(43, 2-59, 6)
13	Max. pulmonary ven-	♂	39, 8(30, 9-43, 5)	61, 8(44, 1-75, 2)	70, 5(50, 0-77, 5)	75, 2(58, 1-105, 0)	112, 9(84, 5-140, 3)	110, 3(79, 6-139, 3)	122, 0(91, 5-160, 3)
14	tilation[1], L/min	♀	33, 9(31, 0-38, 9)	57, 3(48, 2-67, 6)	61, 1(46, 2-80, 9)	79, 9(65, 5-102, 6)	87, 9(68, 4-100, 7)	93, 8(73, 6-119, 1)	92, 2(74, 4-114, 8)
15	Max. respiratory	♂	70, 4(63-90)	67, 0(55-83)	57, 9(32-77)	54, 1(31-68)	52, 9(39-68)	44, 7(28-60)	39, 9(27-59)
16	rate	♀	66, 4(56-81)	67, 1(54-94)	61, 3(51-82)	54, 4(41-88)	51, 6(40-58)	51, 2(44-60)	46, 0(28-63)
17	Max. respiratory	♂	0, 60(0, 43-0, 87)	1, 05(0, 72-1, 25)	1, 33(1, 12-1, 62)	1, 59(1, 02-2, 54)	2, 52(1, 62-3, 26)	2, 77(1, 68-3, 40)	3, 05(2, 26-4, 72)
18	depth, L	♀	0, 52(0, 40-0, 58)	0, 91(0, 64-1, 22)	1, 04(0, 85-1, 33)	1, 46(1, 28-2, 54)	1, 87(1, 34-2, 41)	1, 95(1, 43-2, 28)	2, 10(1, 64-3, 29)
19	Max. blood lactic	♂	56, 3(33-76)	82, 0(60-110)	84, 0(50-125)	79, 1(45-143)	90, 4(74-113)	104, 9(83-138)	112, 0(71-158)
20	acid, mg/100ml	♀	60(51-69)	76, 5(64-85)	82, 2(56-116)	97, 6(76-119)	100, 5(73-145)	110, 2(77-144)	103, 6(69-134)

[1] Body temperature, pressure; saturated. [2] Standard temperature, pressure, density.

320. PHYSIOLOGICAL EFFECTS, SUBMAXIMAL WORK: MAN

Values are for young adults (20-30 yr) doing submaximal work on the bicycle ergometer. Values in parentheses are estimate "b" of the 95% range (cf. Introduction).

	Sex	Work Intensity		O_2 Intake[1]	Net Efficiency	O_2 Intake [% of Max Intake]	Heart Rate	Ventilation[2]	Ventilation[2] per L O_2 Intake	Ventilation [% of Max Vent.]
		kg m/min		L/min	%	%	/min	L/min	%	%
1	♀	600		1, 48(1, 32-1, 64)	22, 5(19, 2-25, 8)	52(41-63)	138(115-161)	34, 7(24, 9-44, 5)	23, 4(18, 5-28, 3)	39(27-51)
2	♀	900		2, 06(1, 88-2, 24)	23, 1(20, 9-25, 3)	73(60-86)	168(143-193)	50, 6(37, 3-63, 9)	24, 5(19, 2-29, 8)	56(38-74)
3	♂	900		2, 09(1, 90-2, 28)	23, 4(21, 1-25, 7)	50(42-58)	128(105-151)	41, 9(32, 1-51, 7)	20, 1(15, 7-24, 5)	34(23-45)
4	♂	1200		2, 67(2, 44-2, 90)	23, 7(21, 4-26, 0)	64(51-77)	148(125-171)	55, 2(41, 1-69, 3)	20, 6(15, 8-25, 4)	45(30-60)
5	♂	1500		3, 33(3, 00-3, 66)	23, 3(21, 0-25, 6)	79(67-91)	167(144-190)	70, 9(55, 3-86, 5)	21, 1(16, 9-25, 3)	58(39-77)

[1] Standard temperature, pressure, density. [2] Body temperature, pressure, saturated.

Values are to be considered as "estimates" because the newborn period is not a time when measurements are likely to be "normal." Ranges of values obtained from normal infants vary widely with the day of life and even with the hour within the first day. Variation will also depend on whether the cord is clamped early or late and whether the infant is full term or premature. The relatively high immunity to the usual infectious diseases of infants during the first 6-12 months of age is generally attributed to immune bodies obtained in utero by placental passage.

Part I: CHEMICAL AND PHYSICAL PROPERTIES

	Variable	Age[1] Birth	Age[1] One Week
	Blood		
1	Calcium serum, mg/100 ml	11.3(7.3-17)	10.5(7.5-13.9), IV-VII
2	Cholesterol, ester, plasma, mg/100 ml	82(50-130), I	140(100-190), V-XI
3	Cholesterol, free, plasma, mg/100 ml	32(22-44), I	50(40-70), V-XI
4	Citric acid, serum, mg/100 ml	(3-6)	
5	Fat, neutral, plasma, mg/100 ml	80(10-150), I	175(90-270), V-XI
6	Hemoglobin, capillary, g/100 ml	19.9(14-27)	19.4(14.2-25.5)
7	Hemoglobin, venous or cord, g/100 ml	17(13-24)	19(15-25)
8	Iron, serum, μg %	(30-120)	114(70-200), VI
9	Lipids, total, plasma, mg/100 ml	221(120-320), I	470(300-650), V-XI
10	Nitrogen, blood urea, mg/100 ml	17(13-19), III	14(13-15)
11	Nitrogen, non-protein, mg/100 ml	54(44.5-61), III	40(26.5-48)
12	Phosphatase, serum, Bodansky units	7(4.5-10), I-III	9(6.5-11), IV-XIV
13	Phosphatides, plasma, mg/100 ml	27(0-94), I	100(20-200), V-XI
14	Phosphorus, serum, mg/100	5.5(4.2-8)	5.9(3.5-7.6), IV-VII
15	Protein, total, serum, g/100 ml[2]	6(5.0-7.5)	
	Bone Marrow		
16	Leukocytes, total, thousands/cu mm	186(54-358)	134(53-327), VIII
	Differential cell count, % of total		
17	Basophil	0	0, VIII
18	Eosinophil	2	1.7, VII
19	Erythroblast	1(0-5.2)	0.5(0-2.6), VIII
20	Erythrocyte, nucleated, total	31.9(16.4-49)	11.6(5-23, VIII
21	Lymphocyte	3.8	6.2, VIII
22	Megakaryocyte	0.1	0.1, VIII
23	Megaloblast	0.1	0.1, VIII
24	Myeloblast	0.8	1.5, VIII
25	Myelocyte, eosinophilic	0.6	0.6, VIII
26	Myelocyte, neutrophilic	16.3(7-29.6)	19.7(8-34), VIII
27	Neutrophil, non-segmented	33.9(16.4-46)	43.5(15.4-61), VIII
28	Neutrophil, segmented	7(0-17)	10.4(10-29.4), VIII
29	Normoblast	30.8(16.2-44.6	11(4.4-22.4), VIII
30	Reticulum cell	0	0.1, VIII

	Variable	Age[1] Birth	Age[1] One Week
	Miscellaneous		
31	Blood pressure, systolic/diastolic, mm Hg	80/40	92/50
32	Bleeding time, min (Duke's method)	(1.5-2.5)	
33	Cardiac output, ml/min	528(313-696)	580(438-855)
34	Circulation time, umbilical vein to lip, sec[3]	4.8(3.1-7)	
35	Circulation time, sinus venosum to lip, sec[3]	4.4(3.3-5.8)	
36	Clotting time, normal plasma, min	4	4
37	Clotting time, platelet free plasma, min	5	7
38	Erythrocytes, capillary, millions/cu mm	5.6(4-7.5)	
39	Erythrocytes, venous or cord, millions/cu mm	4.8(3.8-6)	5.3(3.6-7.6)
40	Erythrocytes, corpuscular volume, cu μ	113(90-124)	107(90-124)
41	Erythrocytes, nucleated, % nucleated cells	7(0-15)	> 1%, III
42	Hematocrit, venous	53(45-60)	55(42-66)
43	Platelets, capillary, thousands/cu mm	227(140-290)	233(160-320)
44	Prothrombin time, venous, % of normal	76(37-100)	86(69-100), V
45	Pulse, beats/min	112(96-130), I	119(103-133)
46	Respiration rate, breaths/min	25(14-34)	28(18-40)
47	Reticulocytes, % total erythrocytes	4.4(2.5-6.5)	1.1(0.1-4.5)
48	Tidal air, ml	(15-25)	(15-25)
49	Urine, pH	5.7(5.2-6.3), I	6.4(5.2-7.2)
50	Urine, specific gravity[4]	1.012(1.008-1.018), I	1.009(1.005-1.011)
51	Volume, blood[5], % body wt	9.4(7.2-12.8)	9.6(8-13.8), III
52	Volume, blood[6], % body wt	12.2(8-14.9)	12.1(8.2-16.2), III
	White Blood Cells		
53	Leukocytes, total, thousands/cu mm blood	18(9-30)	12(5-21)
	Differential leukocyte count, % of total		
54	Basophil	0.1(0-0.6)	0.05(0-0.25)
55	Eosinophil	0.4(0.02-0.9)	0.5(0.07-1.1)
56	Lymphocyte	5.5(2-11)	5(2-17)
57	Monocyte	1.1(0.4-3.1)	1.1(0.3-2.7)
58	Neutrophil, banded	1.6	0.8
59	Neutrophil, segmented	9.4	6.7
60	Neutrophil, total	11(6-26)	5.5(1.5-10)

/1/ Roman numerals indicate age in days when age varies from column headings. /2/ Cord blood. /3/ Fluorescein. /4/ RENAL FUNCTION TESTS. I. Glomerular filtration of H_2O: (a) Inulin Clearance (C_{IN}) for infants 6-30 ds of age = 30-50% of adult value; C_{IN} = 48 ml/min/1.73 sq m Body Surface Area (BSA). (b) Creatinine Clearance/Inulin Clearance (C_{CR}/C_{IN}) = 1.000(0.86-1.39). II. Effective Renal Plasma Flow: p-Aminohippurate (PAH) or Diodrast at low (0.5-3 mg/100 ml) plasma concentration = 20-40% of adult value or 135-270 ml/min/1.73 sq m BSA. III Maximal Rate of Tubular Excretion: PAH or Diodrast at high (50-100 mg/100 ml) plasma concentration = 15-40% of adult value or 11.5-30.8 mg/min/1.73 sq m BSA. IV. Maximal Rate of Tubular Resbsorption: Glucose Clearance at high (up to 300 mg %) plasma concentration = 10-30% of adult value or 30-100 mg/min/1.73 sq m BSA. V. Urea clearance = 1.00 ml/min or 7.7 ml/min/1.73 sq m BSA when blood urea nitrogen (BUN) = 19(12-26) mg/100 ml, normal value. Maximal clearance, when BUN = 34(23.4-34.6) mg/100 ml, = 2 ml/min or 14.4 ml/min/1.73 sq BSA. /5/ Early clamped cord. /6/ Late clamped cord.

Part II: ORGAN AND BODY WEIGHTS AT GESTATION INTERVALS

	Organ	Interval (days) between First Day of Last Menstrual Period and Delivery: 167	195	217	248	258	272	279	287	291
		250-750	750-1250	1250-1750	1750-2250	Body Weight, g 2250-2750	2750-3250	3250-3750	3750-4250	Over 4250
						Organ Weights, g				
1	Adrenals	2.5	3.3	4.3	5.3	6.9	7.6	9.3	10.5	12.5
2	Brain	82.8	160.6	226.3	289.2	332.6	390.9	429.6	402.9	456.0
3	Heart	4.6	7.6	10.8	14.5	17.9	20.1	21.7	25.4	29.3
4	Kidneys	5.3	9.7	13.6	18.3	21.1	23.6	26.6	29.3	32.2
5	Liver	31.5	49.2	66.3	87.9	105.8	140.4	151.5	185.1	229.0
6	Lungs	15.0	25.2	33.7	44.2	49.5	54.7	59.4	64.0	77.9
7	Pancreas	0.6	1.2	1.6	2.1	2.8	3.4	3.6	3.9	4.6
8	Spleen	1.0	2.1	4.0	5.8	7.6	9.7	11.1	12.2	13.0
9	Thymus	1.4	3.1	5.1	8.5	9.3	9.9	10.8	15.3	12.8
10	Thyroid	0.5	4.1	1.1	1.4	1.8	1.8	2.4	2.4	2.9

Values are for males only unless otherwise indicated. Ranges in parentheses on Lines 1–39 conform to estimates "b," and those on Lines 43–46 to "d" of the 95% range (cf Introduction). Differences between values presented here and those in other tables giving more detailed data on one or more of the variables may be attributed to the differences in the sample of "normal" subjects studied by different investigators. The purpose of this table is to indicate the change (if any) of a variable with age, rather than to present a set of "standard values" for each age group.

	Variable	Age Group, yr					
		20–29	30–39	40–49	50–59	60–69	70–79
1	Plasma volume, ml/kg body weight	42.3(31.1–53.5)	45.5(34.7–56.3)	42.3(36.3–48.3)	50.8(35.6–66.0)	46.6(32.2–61.0)	47.2(34.4–60.0)
2	Total blood volume, ml/kg body weight	77.3(61.1–93.5)	81.9(65.9–97.9)	73.5(61.3–85.9)	86.1(67.3–104.9)	78.3(58.1–98.5)	80.7(58.7–102.7)
3	Plasma vitamin A, μg/100 ml			47.6(28.6–66.6)	55.0(16.0–77.0)	49.9(22.7–77.1)	47.1(17.9–76.3)
4	Plasma β-carotene, μg/100 ml			126.7(62.7–210.7)	128.3(43.3–213.3)	111.0(22.0–200.0)	106.0(28.2–183.8)
5	Blood pH, capillary serum, 38°C	7.40(7.34–7.46)	7.38(7.33–7.45)	7.38(7.32–7.44)	7.38(7.34–7.42)	7.38(7.34–7.42)	7.37(7.33–7.41)
6	Total blood CO_2 content, capillary, mM/L	22.8(20.1–25.5)	22.8(19.9–25.7)	22.6(19.6–25.6)	22.3(18.8–25.8)	22.3(18.2–26.4)	22.3(19.4–25.2)
7	CO_2 tension, arterial blood, mm Hg	44.8(38.3–51.3)	45.2(38.3–52.1)	46.1(38.1–54.9)	45.0(36.2–53.8)	45.3(36.5–54.1)	45.8(38.9–52.7)
8	Serum bicarbonate content, arterial, mM/L	26.5(23.2–29.8)	26.5(23.2–29.8)	26.8(22.4–31.2)	26.0(21.9–30.1)	26.2(21.5–30.9)	25.8(22.3–29.3)
9	Cell volume, % red cells	47(43–51)	47(41–53)	48(36–60)	44(36–52)	45(39–51)	43(35–51)
10	Blood non-protein nitrogen, mg/100 ml			27.2(18.4–36.0)	27.2(19.2–35.2)	27.7(20.7–34.7)	28.5(18.5–28.5)
11	Blood urea nitrogen, mg/100 ml	9.7(4.7–14.7)	10.7(3.5–17.9)	10.6(4.4–16.8)	12.3(6.5–18.1)	13.5(6.3–20.7)	12.9(6.5–19.3)
12	Blood glucose, venous, mg/100 ml	82.1(68.9–95.3)			78.9(54.9–102.9)	79.0(62.0–96.0)	79.6(67.2–92.0)
13	Thiocyanate space (extracellular H_2O), L/sq m body surface area			17.0(10.6–23.4)	16.8(11.4–22.2)	16.3(12.3–20.3)	16.1(10.5–21.7)
14	Antipyrine space (total body H_2O), L/sq m body surface area			34.6(22.0–47.2)	33.1(20.9–45.5)	31.9(23.1–40.7)	30.2(20.4–40.0)
15	Heart rate, per min	77(52–102)	72(48–96)	70(50–90)	70(52–88)	63(43–83)	66(44–88)
16	Eye, minimum light threshold, 30 min dark adaptation, log $_{m}$Lamberts	2.62(2.08–3.16)	2.67(1.79–3.55)		2.84(2.06–3.62)	3.16(2.22–4.10)	3.85(1.63–6.07)
17	Eye, pupil diameter (in light), mm	5.11(3.70–6.52)	4.64(3.27–6.01)	4.09(2.48–5.70)	3.77(2.20–5.34)	3.48(1.89–5.07)	3.52(2.15–4.89)
18	Eye, pupil diameter (in dark), mm	7.42(6.15–8.69)	6.72(4.96–8.48)	5.91(3.85–7.97)	5.89(3.75–8.03)	4.78(2.70–6.86)	5.10(3.53–6.67)
	Kidney function						
19	Tm glucose, mg/min/1.73 sq m body surface area	358.7	333.6(221.2–446.0)	315.1(224.7–405.5)	308.2(178.2–438.2)	260.2(131.0–389.4)	239.3(146.5–332.0)
20	Inulin clearance, ml/min/1.73 sq m B.S.A.	122.8(90.0–155.8)	115.0(93.4–136.6)	121.2(74.6–167.8)	99.3(70.1–128.5)	96.0(45.0–147.0)	89.0(49.2–128.8)
21	Diodrast clearance, ml/min/1.73 sq m B.S.A.	613.5(464.3–762.7)	649.3(414.7–883.9)	573.8(350.6–797.0)	500.4(326.4–674.4)	442.1(281.5–602.7)	354.0(187.2–520.5)
22	PAH clearance, ml/min/1.73 sq m B.S.A.		615.2(409.2–821.2)	511.8(289.0–734.6)	460.4(196.6–724.2)	429.7(244.7–614.7)	292.8(198.0–396.6)
23	Urea clearance, ml/min/1.73 sq m B.S.A.	63.1(30.7–95.5)	60.6(36.4–84.8)	64.6(42.4–86.8)	57.7(33.5–81.9)	46.9(26.5–67.3)	46.3(22.7–73.9)
24	Tm diodrast, mg/inulin/1.73 sq m B.S.A.	54.6(35.6–73.6)	51.0(33.8–68.2)	45.9(30.3–69.5)	45.3(32.8–58.0)	44.5(26.3–62.7)	39.1(24.5–53.7)
25	Tm PAH, mg/min/1.73 sq m B.S.A.		90.6(55.4–125.8)	83.4(50.8–116.0)	74.0(39.2–108.8)	67.2(40.9–93.5)	59.0(35.6–82.4)
26	Conduction velocity of ulnar nerve, m/sec	57.7(37.1–78.3)	58.8(45.1–72.5)	55.6(36.0–75.2)	53.6(36.9–70.3)	52.0(33.5–66.9)	52.6(32.0–73.2)
27	Basal metabolism, cal/sq m/hr			35.7(28.1–43.3)	34.5(25.7–43.3)	33.0(25.9–40.1)	32.6(25.3–39.9)
28	Oxygen uptake, ml/sq m/min			123.5(99.0–148.1)	121.9(86.2–157.6)	112.9(87.4–138.4)	113.1(87.6–136.6)
29	CO_2 elimination, ml/sq m/min			99.7(81.1–118.3)	98.9(75.0–122.8)	93.4(72.0–114.8)	90.5(68.4–112.6)
30	Ventilation volume, L/sq m/min			3.97(2.62–5.32)	4.03(2.70–5.36)	3.93(2.26–5.60)	4.13(2.78–5.48)
31	Cardiac output (cardiac index), L/sq m/min	3.72(2.04–5.40)	3.54(1.64–5.44)	2.96(1.46–4.46)	2.78(1.74–3.82)	2.58(1.52–3.64)	2.54(1.46–3.62)
32	Stroke index, ml/beat/sq m	48.9(30.7–67.1)	49.4(25.8–73.0)	43.3(24.9–61.7)	40.3(23.3–57.3)	41.5(24.3–58.7)	39.3(20.1–58.5)
33	Circulation time, arm to arm, sec	12.0(7.8–16.2)	13.5(7.9–19.1)	13.7(9.3–18.1)	13.9(7.5–20.2)	15.0(10.0–20.0)	14.9(9.5–21.3)
	Pulmonary function						
34	Resting tidal volume, ml/sq m	301(183–419)	297(155–438)	315(123–507)	338(184–492)	302(176–428)	305(175–432)
35	Vital capacity, supine, L/sq m B.S.A.	2.37(1.40–3.33)	2.19(1.36–3.03)	1.94(1.00–2.89)	1.89(1.26–2.53)	1.63(0.76–2.49)	1.40(0.74–2.07)
36	Vital capacity, standing, L/sq m B.S.A.	2.55(1.55–3.55)	2.35(1.52–3.18)	2.14(1.09–3.18)	2.04(0.35–2.73)	1.77(0.93–2.61)	1.51(0.79–2.23)
37	Total lung volume, L/sq m B.S.A.	3.06(1.95–4.17)	2.96(1.90–4.01)	2.88(1.87–3.90)	3.24(2.41–4.07)	2.78(1.82–3.74)	2.83(1.78–3.89)
38	Residual lung volume, L/sq m B.S.A.	0.70(0.29–1.10)	0.79(0.34–1.25)	0.95(0.32–1.59)	1.35(0.42–2.27)	1.15(0.33–1.97)	1.44(0.71–2.17)
39	Maximum breathing capacity (15 sec), L/sq m B.S.A.	69.5(29.5–109.5)	62.3(29.3–95.3)	58.3(19.7–96.9)	43.7(15.7–71.7)	40.4(8.6–72.2)	32.6(9.4–55.8)
	Gastric secretion[1]						
40	Total volume, ml	113.5 ♀99.0	109.5 ♀97.7	103.0 ♀95.0	96.3 ♀93.7	92.7 ♀85.5	91.0 ♀79.0
41	Free acidity, ml N/10 NaOH/100 ml	47.0 ♀33.0	47.0 ♀33.0	46.0 ♀33.0	42.6 ♀33.3	38.3 ♀33.5	33.5 ♀33.5
42	Total acidity, ml N/10 NaOH/100 ml	62.5 ♀50.5	61.7 ♀50.5	58.9 ♀50.5	57.6 ♀50.5	54.6 ♀50.5	50.5 ♀50.5
	Hearing loss >45 db, % individuals[2]						
43	At 440–880 cycles/sec	(0.0–0.1) ♀(0.1–0.4)	(0.3–1.1) ♀(0.8–1.2)	(1.4–1.7) ♀(0.6–2.1)	(2.2–2.6) ♀(0.7–4.0)	4.7 ♀1.2	
44	At 1760 cycles/sec	(0.0–0.3) ♀0.3	(0.6–1.2) ♀(0.8–1.4)	(2.6–3.6) ♀(1.5–2.0)	(6.0–8.4) ♀(2.2–3.0)	18.0 ♀9.0	
45	At 3520 cycles/sec	(2.7–5.0) ♀(0.3–0.7)	(6.0–7.0) ♀(0.6–1.6)	(13–16) ♀(2.4–3.0)	(27–30) ♀(2.7–7.0)	45.0 ♀12.0	
46	At 7040 cycles/sec	6.7 ♀0.0	7.1 ♀1.4	13.9 ♀3.4	35.1 ♀6.1	49.6 ♀23.6	

/1/ Test meal: 400 ml H_2O and 8 tapioca biscuits. /2/ Samples taken at San Diego County Fair (1948) and World's Fair (Chicago, 1933).

323. EQUATIONS RELATING QUANTITATIVE VALUES WITH BODY WEIGHTS: MAMMALS

Adapted from Adolph, E. F., Science 109:579-585 (1949).

	Variable	Symbol	Value		Variable	Symbol	Value
1	Water intake, ml/hr	I	$=.010\ B^{.88}$	17	Sulfur output, g/hr	S	$=.000\ 001\ 71\ B^{.74}$
2	Urine output, ml/hr	U	$=.0064\ B^{.82}$	18	O_2 consum.,liver slices, ml STP/hr	O_L	$=3.3\ B^{.77}$
3	Urea clearance, ml/hr	C_{ur}	$=1.59\ B^{.72}$			H_b	$=.013\ B^{.99}$
4	Inulin clearance, ml/hr	C_{in}	$=1.74\ B^{.77}$	19	Hemoglobin weight, g	M_y	$=.000\ 039\ B^{1.31}$
5	Creatinine clearance, ml/hr	C_{cr}	$=4.2\ B^{.59}$	20	Myoglobin weight, g	P_c	$=.000\ 10\ B^{.84}$
6	Diodrast clearance, ml/hr	C_{di}	$=2.14\ B^{.89}$	21	Cytochrome weight, g	N	$=2600\ B^{.62}$
7	Hippurate clearance, ml/hr	C_{PAH}	$=5.4\ B^{.80}$	22	Nephra number	D	$=.0081\ B^{.98}$
8	O_2 consum.,basal, ml STP/hr	O	$=3.8\ B^{.734}$	23	Diameter,renal corp., cm	K	$=.0212\ B^{.85}$
9	Heartbeat duration, hr	H	$=.000\ 0119\ B^{-.27}$	24	Kidneys,weight, g	E	$=.081\ B^{.70}$
10	Breath duration, hr	Q	$=.000\ 047\ B^{-.28}$	25	Brain weight, g	J	$=.0066\ B^{.98}$
11	Ventilation rate, ml/hr	V	$=120\ B^{.74}$	26	Heart weight, g	F	$=.0124\ B^{.99}$
12	Tidal volume, ml	T	$=.0062\ B^{1.01}$	27	Lungs,weight, g	L	$=.082\ B^{.87}$
13	Gut beat duration, hr	G	$=.000\ 093\ B^{.31}$	28	Liver weight, g	M	$=.000\ 32\ B^{.92}$
	Nitrogen			29	Thyroid, weight, g	A	$=.0011\ B^{.80}$
14	Total output, g/hr	N_T	$=.000\ 074\ B^{.735}$	30	Adrenals,weight, g	P	$=.000\ 13\ B^{.76}$
15	Endogenous output, g/hr	N_E	$=.000\ 042\ B^{.72}$	31	Pituitary weight, g	W	$=.112\ B^{.74}$
16	Creatinine-N output, g/hr	N_{cr}	$=.000\ 001\ 09\ B^{.90}$	32	Stomach + intestines, weight, g	R	$=.055\ B^{.99}$
				33	Blood weight, g		

Equations (Derived) Interrelating Quantitative Properties

34	$U = .46\ T^{.93} = .0108\ C_{ur}^{1.14} = .000,000\ 19\ N^{1.32}$	37	$V = 370,000,000,000,000\ H^{2.74} = 4900\ T^{.73}$
35	$C_{ur} = .35\ C_{PAH}{}^{.90} = 17,700\ N_T{}^{.98} = 42\ K^{.85}$	38	$N_T = .0068\ B^{.90} = 5.4\ N_{cr}{}^{.82} = .000,0162\ C_{cr}{}^{1.06}$
36	$O = 1300,000,000,000\ H^{2.72} = 11,900\ P^{.87}$	39	$O_L = 30\ L^{.89} = .81\ O^{1.05} = 1290\ M_y{}^{.59}$

324. ALIGNMENT CHART RELATING QUANTITATIVE VALUES: MAMMALS

The characteristics of one animal are read off along a horizontal straight-edge placed at a known value in any one of the variables. Several species chosen at random are indicated on the left at the appropriate scale positions. Ordinates are numbered as exponents of 10; but the subdivisions between ordinates read arithmetically. Thus, the number 1 means 10^1 and the subdivisions above it mean 20, 30, 40, etc. All values are in ml, g, cm, and hr, as shown in Table 323. The lines and scales represent, and are derived from, the equations of Table 323. Adapted from Adolph, E. F., Science 109:579-585 (1949).

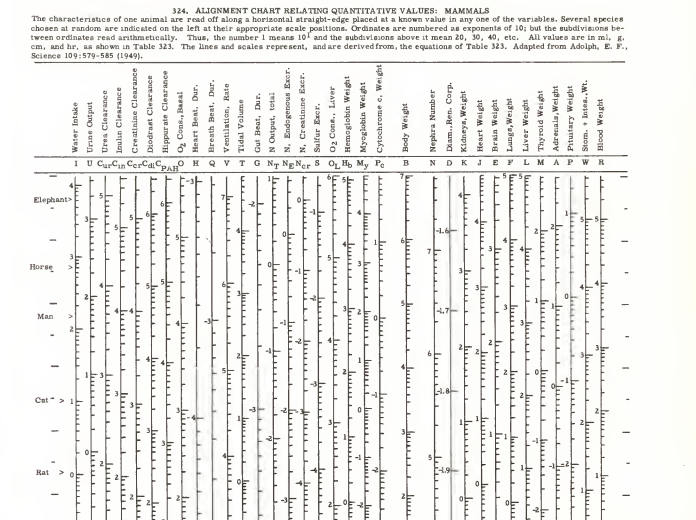


Table adapted from D. W. Woolley's "A Study of Antimetabolites," John Wiley and Sons, 1952.

Part I. SOME METABOLITES AND THEIR ANTAGONISTIC STRUCTURAL ANALOGS

	Metabolite	Analog	Structural Alteration	Biological System Affected
1	Acetic acid	Fluoroacetic acid	F for H	Aconitase
2	Adenine	Benzimidazole and derivatives	2 C for 2 N, side-chain alterations	Microorganisms, animals
		Triazolopyrimidines	N for C	Microorganisms
		Diaminopurine	NH_2 for H	Bacteria
3	α-Alanine	Glycine	H for CH_3	Bacteria
4	β-Alanine	β-Aminobutyric acid	CH_3 for H	Yeast
		Propionic acid	H for NH_2	Bacteria
		Asparagine	$COOH$ for H, $CONH_2$ for $COOH$	Yeast
5	Arginine	Canavanine	O for CH_2	Bacteria
6	Aspartic acid	Hydroxyaspartic acid	OH for H	Bacteria
		Asparthenone	C_4H_6 for OH	Bacteria
7	Ascorbic acid	Glucoascorbic acid	Addition of CHOH and optical inversion	Animals, liver enzymes
8	p-Aminobenzoic acid	Sulfanilamide and derivatives	SO_2NH_2 or derivative for $COOH$	Microorganisms
		p-Aminobenzamide	$CONH_2$ for $COOH$	Bacteria
		Carbarsone and related arsenicals	As for C in a $COOH$ group; derivatives of this	Microorganisms, animals
		Phosphanilic acid	PO_3H_2 for $COOH$	Microorganisms
		Heterocyclic acids[1]	N or C	Bacteria
		Ring-substituted PAB	Halogen or alkyl for H	Bacteria
		p-Aminoacetophenone and derivatives	COR for $COOH$	Bacteria
		p-Nitrobenzoic acid	NO_2 for NH_2	Bacteria
9	Biotin	Desthiobiotin and derivatives	2 H for S	Microorganisms
		Biotin sulfone	SO_2 for S	Microorganisms
		Ureylenecyclohexyl aliphatic acids	2 C for S; and derivatives with shorter side chains	Microorganisms
		Desthioisobiotin	Loss of S, geometric isomerism	Insects
		Ureyleneterahydrofuryl aliphatic sulfonic acids	O for S, SO_3H for $COOH$	Microorganisms
		Homobiotin	Addition of - CH_2 -	Microorganisms
10	Choline	Triethyl choline	3 ethyls for 3 methyls	Frog muscle and mice
11	Cocarboxylase	Thiamine-thiazole pyrophosphate	Loss of pyrimidine portion	Carboxylase
12	Cis- or trans-crocetin dimethyl ester	Trans- or cis-crocetin dimethyl ester	Geometric isomerism	Algae
13	Cytidine	Adenosine	OH for H, loss of imidazole ring	Neurospora mutant
14	Desthiobiotin	2-Oxyimidazole aliphatic acids	H for CH_3	Microorganisms
15	Glutamic acid	Methionine sulfoxide	$SOCH_3$ for $COOH$	Bacteria
		Hydroxyglutamic acid	OH for H	Bacteria
		N-Alkylglutamines	N-Alkyl for OH	Bacteria
16	Guanine	Triazolopyrimidines	N for C	Bacteria
		Benzimidazole	2 C for 2 N	Microorganisms
17	Histamine	Imidazole and derivatives	Elimination or substitution, part of molecule	Smooth muscle, histamine shock in animals
		Diphenhydramine	Opening of ring, O for N, alkylation of N, C	
		Tripelennamine	Opening of ring, alkylation of N	
18	Hypoxanthine	Hydroxytriazolopyrimidine	N for C	Bacteria
19	Indoleacetic acid	Phenyl butyric acid	Elimination of N and shift of one C	Plants
		Skatyl sulfonic acid	SO_3H for $COOH$	Plants
20	Inositol	Hexachlorocyclohexane	6 Cl for 6 OH	Fungi, plants, pancreatic amylase
21	Isoleucine	Leucine	Position isomerism of one CH_3	Bacteria
22	Leucine	α-Leucine	Optical inversion	Bacteria
23	Lysine	Arginine	Guanidino for amino, elimination of CH_2	Neurospora mutant
24	Methionine	Methoxinine	O for S	Bacteria
		Ethionine	CH_3 for H	Bacteria and animals
		Norleucine	CH_2 for S	Bacteria
25	Nicotinic acid, (or amide)	Pyridine-3-sulfonic acid or amide	SO_3H for $COOH$	Microorganisms; animals[2]
		3-Acetylpyridine	$COCH_3$ for $COOH$	Animals, not in microorganisms
		5-Thiazole carboxamide	S for CH=CH	Certain bacteria
26	Pantothenic acid[3]	Thiopanic acid (pantoyltaurine) and derivatives	SO_3H and derivatives for $COOH$	Microorganisms, pantothenate-utilizing enzymes, not animals
		Pantothenyl alcohol	CH_2OH for $COOH$	Microorganisms, not animals
		α- or β-Methyl pantothenic acid	CH_3 for H	Microorganisms
		Other substituted panto-amides	Alkyl- and NH_2-alkyl for CH_2CH_2COOH	Microorganisms
		Phenyl pantothenone	COC_6H_5 for $COOH$	Microorganisms
		Salicylyl β-alanine	o-Hydroxy-benzoyl for pantoyl	Microorganisms
		γ'-Methyl pantothenic acid	CH_3 for H	Bacteria
27	Phenylalanine	β-Hydroxyphenylalanine	OH for H	Bacteria
		Thienylalanine	S for CH=CH	Microorganisms, animals
		Furylalanine	O for CH=CH	Microorganisms
		Halogenated phenylalanines	Halogen for H	Microorganisms
28	Pimelic acid	2,4-Dichlorosulfanilidocaproic acid	Dichlorosulfanilide for $COOH$	Biotin indepit. microorganisms
29	Porphyrins[4]	Porphyrins lacking vinyl groups		Bacteria
30	Pteroylglutamic acid	Pteroyl-triglutamic acid	Addition of two glutamic acids	Transplanted tumors
		Xanthopterin	Loss of p-amino-benzoyl glutamic acid	Transplanted tumors
31	Pyridoxine	Desoxypyridoxine	H for OH	Microorganisms, animals
		2-Ethyl-3-amino-4-ethoxymethyl-5-amino-methyl pyridine	CH_3 for H, NH_2 for OH, Et for H	Microorganisms
32	Riboflavin	6,7-Dichlororiboflavin	2 Cl for 2 CH_3	Microorganisms
		Isoriboflavin	Shift in position of CH_3	Animals, not bacteria
		Corresponding phenazine	2 C for 2 N, 2 NH_2 for 2 OH	Microorganisms, animals
		Galactoflavin	Dulcityl for ribityl	Animals
		Lumiflavin	CH_3 for ribityl	Bacteria
		Arabioflavin	Inversion of position of OH	Animals

/1/ e.g., 6-Aminonicotinic acid. /2/ Alcohol and lactic dehydrogenases, not animals in vivo. /3/ See also table on next page. /4/ e.g., hematin and protoporphyrin.

Table adapted from D. W. Woolley's "A Study of Antimetabolites," John Wiley and Sons, 1952.

Part I: SOME METABOLITES AND THEIR ANTAGONISTIC STRUCTURAL ANALOGS (Concluded)

	Metabolite	Analog	Structural Alteration	Biological System Affected
33	Succinic acid	Malonic acid	Loss of CH_2	Succinic oxidase
		Sulfonated succinic acid	SO_3H for H	Succinic oxidase
34	Testosterone	Estradiol	Benzene ring for cyclohexane ring, loss of CH_3	Animals
35	Thiamine	Pyrithiamine	CH=CH for S	Microorganisms, animals
		Oxythiamine	OH for NH_2	Animals, fish thiaminase
		Butylthiamine	Butyl for CH_3	Animals
		Aminobenzylmethylthiazolium chloride	2 C for 2 N, loss of side chains	Fish thiaminase
36	Thymine	5-Substituted dioxypyrimidines	NO_2 or Br or NH_2 or OH for CH_3	Bacteria
		2, 4-Diamino-or dithiothymine	NH_2 or SH for OH	Bacteria
37	α-Tocopherol	α-Tocopherol quinone	Opening of ring by addition of O	Animals
38	Thyroxine	Ethers of diiodotyrosine	p-Nitrobenzyl or p-nitrophenylethyl or benzyl for p-hydroxydiiodophenyl	Tadpoles
39	Tryptophan	Indole acrylic acid	Loss of NH_2	Bacteria
		Naphthylacrylic acid	Loss of NH_2, C=C for N	Bacteria
		Styrylacetic acid	Loss of NH_2, substitution of aliphatic unsaturated side chain for pyrrol ring	Bacteria
		Methyltryptophans	CH_3 for H	Bacteria
		Benzothienylalanine	S for N	Bacteria
		Indole	Loss of side chain	Bacteriophage plus bacteria
40	Tyrosine	3-Fluorotyrosine	F for H	Rats
41	Uracil	Barbituric acid	OH for H	Bacteria
		Thiouracil	S for O	Bacteria, plant seed germination
42	Vitamin K	Dicumarol and derivatives	O for C, side-chain alterations	Animals
		Jodinan	2 N for 2 C, side-chain alterations	Bacteria
		α-Tocopherol quinone	2 CH_3 for benzene ring	Animals
		2, 3-Dichloronaphthoquinone	2 Cl for alkyl side chains	Microorganisms
		2-Substituted-3-hydroxynaphthoquinones	OH for H, change in alkyl substituent	Animals, not bacteria
		Methoxynaphthoquinone	OCH_3 for CH_3	Microorganisms

Part II: SOME ANTIMETABOLITES TO PTEROYLGLUTAMIC ACID

	Structural Alteration	Organisms Affected	Reversing Effect of Folic Acid
1	x-CH_3 for H (x = 7 or 9)	Bacteria, chickens, rats, mice, swine, insects	Competitive
2	10-CH_3 for H	Bacteria	Competitive
3	10-CH_3 for H, loss of glutamic	Bacteria	Competitive
4	4-NH_2 for OH	Bacteria, rats, mice, chickens, guinea pigs, insects, humans	Present in some bacteria, poor or absent in animals
5	4-NH_2 for OH, 10-CH_3 for H	Bacteria, chickens, rats	Poor or absent in animals
6	4-NH_2 for OH, 4-phenyl for aminobenzoyl-glutamic, 7-phenyl for H	Bacteria, not animals	Present
7	6-Phenyl for aminobenzoylglutamic, 7-phenyl for H	Chickens, not bacteria	
8	7-OH for H, 9-O for H	Bacteria, rats	Competitive
9	Aspartic for glutamic	Bacteria, rats, mice, chickens	Competitive
10	Quinoxaline for pteridine	Bacteria, not rats	Competitive

Part III: SOME ANTIMETABOLITES TO PANTOTHENIC ACID

	Antimetabolite	Structural Alteration	Inhibition Index[1]		
			L. arabinosus	Yeast	L. casei
		Alterations of β-Alanine Part			
1	Pantoyltaurine (thiopanic acid)	SO_3H for COOH	1,000		24,000
2	Pantoyltaurine amide	SO_2NH_2 for COOH			6,400
3	Pantoyltaurine anilides	$SO_2NHC_6H_5$ for COOH			
4	Phenylpantothenone	COC_6H_5 for COOH	4,500	Inhibition not reversible	700
5	Tolyl pantothenone	$COC_6H_4CH_3$ for COOH			100
6	Chlorophenyl pantothenone	COC_6H_4Cl for COOH			230
7	α-Methylpantothenic	CH_3 for H			1,000
8	β-Methylpantothenic	CH_3 for H	750		250
9	Pantothenol	CH_2OH for COOH	10,000		20,000
10	Methylpantothenol	$CH(CH_3)OH$ for COOH	50,000		100,000
11	α-Hydroxypantothenic[2]	OH for H	2,500		2,500
12	Pantoic hydrazide	NH_2 for CH_2CH_2COOH			240
13	Monopantoylalkylidiamines	Alkyl diamine for β-alanine			Approx. 100,000
14	Tolyl sulfone of pantothenic	$SO_2C_6H_4CH_3$ for COOH			6,400
15	Anisyl sulfone of pantothenic	$SO_2C_6H_4OCH_3$ for COOH			1,600
16	Pantoylpropylamine	CH_3 for COOH	7,500		10,000
17	Pantoylbutylamine	C_4H_9 for COOH	7,500		15,000
18	Pantoylheptylamine	$(CH_2)_6CH_3$ for COOH	4,500		4,250
19	Pantoylphenylethylamine	C_6H_5 for COOH	40,000		10,000
		Alterations of Pantoyl Part			
20	γ, γ-Dimethyl-δ-hydroxyvaleryl-β-alanine	CH_2CH_2 for CHOH	Inhibitory to streptococci but not reversed by pantothenic		
21	γ-Hydroxybutyryl-β-alanine	Loss of methyls and of α-hydroxy	5,000		300
22	γ'-Methylpantothenic[3]	CH_3 for H		1,600	12,500
23	Salicylyl-β-alanine	Hydroxybenzoic for pantoic			
		Alterations of Both Portions			
24	β-δ-Dihydroxy-γ, γ-dimethylvaleryltaurine	Insertion of CH_2, SO_3H for COOH	Inhibitory to hemolytic streptococci		

/1/ The inhibition index represents the amount of antimetabolite required to overcome the effect of a unit weight of metabolite. The values in this table were calculated from the quantities required to produce maximal inhibition of growth. /2/ Complete inhibition of growth could not be achieved with this compound. /3/ Nomenclature used for pantothenic acid derivatives is sometimes confusing because some investigators name the α-carbon atom of the entire molecule, whereas others take the α-carbon atom of the pantoyl residue as the α-carbon atom. γ'-Methylpantothenic acid might more correctly be named ω-methylpantothenic acid.

Biological antioxidants, as distinct from antioxidants that protect the unsaturated bonds of such materials as gasoline, rubber, and plastics, are compounds that decrease the rate of fatty peroxidase formation and oxygen uptake at carbon-to-carbon unsaturated bonds of food, feed, or tissue lipids. Compounds listed are only a few of the many occurring in living organisms and having antioxygenic activity in vivo or in vitro[1]. Some of the antioxidants are known to be toxic to animals, hence inclusion in the table is not to be construed as endorsement for use in foods or diets for animals. Naturally occurring synergistic type antioxidants (e.g., ascorbic acid, citric acid, cephalin, phosphoric acid, certain amino acids) are not included in this table. Synergistic type antioxidants do not impart any appreciable antioxygenic activity when used alone with a lipid substrate known to be free of inhibitols or other antioxidants, but when used in combination with one or more primary antioxidants they enhance antioxygenic activity.

	Antioxidant and Occurrence	Chemical Name and Composition
1	Arbutin. Leaves of the bearberry (Arctostaphylos uvae-ursi), a small evergreen shrub, and frequently occurs in plants particularly of the Ericaceae family.	Hydroquinone-β-D-glucoside. $C_{12}H_{16}O_7(OH)$.
	Physical and chemical properties	
	Long, fine, silky, bitter tasting, colorless needles. MP (water free product) 194-195°C. Almost insol. in ether; slightly sol. in cold water and in alcohol; easily soluble in hot water. Arbutin hydrate (1 mol H_2O) shows $[\alpha]_D = -60.34°$. Loses water of crystallization at 110-115°C, decomposes on heating to glycosan and hydroquinone. Gives colors with $FeCl_3$, $BiCl_3$, and with HNO_3. Crystallizes from methyl alcohol as hygroscopic anhydrous crystals which acquire 2 mols H_2O at ordinary conditions. Fehling's solution not reduced, but ammoniacal $AgNO_3$ is, on heating.	
2	Gossypol. In the "gland dots," "secretion cavities" or "resin glands" present in all parts of the cotton plant except the woody tissue.	2, 2-bis-1, 6,7-Trihydroxy-3-methyl-5-isopropyl-8-aldehydonaphtyl. $C_{30}H_{24}O_8(OH)_6$
	Physical and chemical properties	
	Brilliant yellow needles, MP 184°C, other crystal forms with MP of 199°C and 214°C; also a red isomeric crystalline form, MP 184-185°C. Very sol. in cold dioxane, diethylene glycol, methyl-, ethyl-, isopropyl-, and butyl alcohols, ether, ethyl acetate, acetone, chloroform, carbon tetrachloride, and pyridine; slightly sol. in glycerol, cyclohexane, and petroleum ether (BP 60-110°C); and insol. in pet. ether (BP 30-60°C), and in water. sol. in fat, alkali salts; very sol. in water and alcohol. Log molal extinction coefficient: (250 $m\mu$) = 5; (300 $m\mu$) ≥ 4; (360 $m\mu$) ≤ 4. Alkaline solutions oxidize readily on exposure to air and are extremely sensitive to oxidizing agents. A number of color reactions occur with metallic and other reagents. O-R potential = + 408 mvolts.	
3	Gum Guaiac. From heart wood resin of tropical American trees, Guaiacum officinale Linn. and Guaiacum sanctum Linn.	Constituents: α- and β-guaiaconic acids (70-5%), guaiaretic (11%), guaialcinic, guaiacretinic, and guaiacic acids, guaiacasponin, vanillin, an aromatic oil, a guttaperchа-like substance called guaispustin, guaiac yellow. Analysis: 87-94% alc. sol., 55-75% ether sol., ash not greater than 3.5%, acid value 46-53; ester value 121-139; sap. value 167-192.
	Physical and chemical properties	
	Occurs in irregular masses enclosing fragments of plant tissues, or large, nearly homogeneous masses, occasionally in round or ovoid tears. Externally brownish black to dusky brown, acquiring a greenish color on long exposure; the fractured surface having a glassy luster, the thin pieces being transluscent and varying in color from brown to yellowish orange. The powder is moderate yellowish brown, becoming olive brown on exposure to air. Balsamic odor and slightly acrid taste. Melting range 85-90°C. Incompletely but readily soluble in alcohol, ether, chloroform, creosote, solutions of alkalis, and in chloral hydrate T.S. Slightly sol. in carbon disulfide and benzene, not readily sol. in fat. An alcoholic solution on addition of $FeCl_3$ tincture or oxidizing agents or enzymes becomes blue changing rapidly to green.	
4	Nordihydroguaiaretic acid. From a desert plant, the creosote bush (Larrea divaricata).	2, 3-bis-[3, 4-Dihydroxybenzyl)-butane. $C_{18}H_{18}(OH)_4$.
	Physical and chemical properties	
	White crystalline solid, MP 184-185°C. Slightly sol. in water and dilute acids; moderately sol. in hot benzene and xylene; very sol. in diethyl ether, alcohol, and glacial acetic acid; sol. in fats to the extent of 0.5%.	
5	Sesamol. Believed to occur as the glucoside sesamolin in sesame oil.	4-Hydroxy-1, 2-methylenedoxy-benzene. $C_7H_5O_2(OH)$.
	Physical and chemical properties	
	Colorless crystals with a phenolic odor, MP 65-8°C. Easily sol. in alcohol and ether; difficultly sol. in water and petroleum ether; sol. in alkali; sol. in conc. H_2SO_4 with a dark green color. Color reactions with aromatic aldehydes in the presence of HCl; gives a carmoisan red color with furfural in presence of HCl; gives color with ferric iron; azo derivatives colored.	
6	Tannins. Widely distributed in vegetable kingdom. May occur in every part of the seed plant.	All contain polyhydroxy phenols or derivatives, often in complex, condensed ring structures. Hydrolyzable with acids to yield phenolic derivatives and in some instances sugars, usually D-glucose. Alkali fusion and dry distillation give decomposition products principally phenolic in character: catechol, pyrogallol, phloroglucinol, resorcinol, and hydroquinone, or their corresponding acids including pyrocatechoic, pyrogallic, and resorcylic.
	Physical and chemical properties	
	Generally amorphous, rarely crystalline materials, having an astringent taste. Readily soluble in hot water to form colloidal sols. Precipated from solution by potassium dichromate, lead acetate, albumin, gelatin, and other proteins, and by alkaloids. Give colors (inks) with ferric salts; sols. develop a red color on the addition of potassium ferri-cyanide. When heated with dilute acids, insoluble, amorphous anhydrides or phlobaphenes produced in addition to hydrolysis products. Phlobephenes are red brown substances practically insoluble in water, chemically relatively inert.	
7	α-Tocopherol (natural or d-form). Non-saponifiable fraction of plant fats and oils; to some extent in land- and marine-animal fats and oils.	5, 7, 8-Trimethyltocol, a chroman derivative. $C_{29}H_{49}O(OH)$.
	Physical and chemical properties	
	Transparent needles, MP 2.5-3.5°C; sol. in fats and fat solv., insol. in water. $E\frac{1\%}{1cm}$ (292 $m\mu$) = 71. Infrared maxima at 3.02 μ for hydroxy and 7.85 μ for phenolic C-O linkage; optically active, dextrorotatory in ethyl alc.; compound has 3 centers of asymmetry: carbon 2 of the chroman ring, and 4', 8' of the side chain; 8 isomers possible. Stable to heat, 200°C, when heated alone in absence of oxygen or to heat, 100°C, in presence of HCl or H_2SO_4. Stable in visible light, unstable in UV light. Acted on by alkali only slowly. Sensitive to oxidation. O-R potential = + 273 mvolts.	
8	β-Tocopherol (natural form). Same occurrence as α-tocopherol.	5, 8-Dimethyltocol. $C_{28}H_{47}O(OH)$.
	Physical and chemical properties	
	Light yellow or colorless oil. $E\frac{1\%}{1cm}$ (297 $m\mu$) = 87.6. O-R potential = + 343 mvolts. Same general properties as those listed for α-tocopherol.	
9	γ-Tocopherol (natural form). Same occurrence as α-tocopherol.	7, 8-Dimethyltocol. $C_{28}H_{47}O(OH)$.
	Physical and chemical properties	
	Transparent needles, MP -3 to -2°C. $E\frac{1\%}{1cm}$ (298 $m\mu$) = 93.2. Infrared maxima at 3.02 μ for hydroxy and 8.17 μ for phenolic C-O linkage. O-R potential = + 348 mvolts. Same general properties as those listed for α-tocopherol.	
10	δ-Tocopherol (natural form). Same occurrence as α-tocopherol.	8-Methyltocol. $C_{27}H_{45}O(OH)$.
	Physical and chemical properties	
	Yellow oil. $E\frac{1\%}{1cm}$ (298 $m\mu$) = 91.2. Infrared maxima at 3.01 μ for hydroxy and 8.28 μ for phenolic C-O linkage. O-R potential = + 405 mvolts. Same general properties as those listed for α-tocopherol.	

[1] Some antioxidants not included are butylhydroxyanisole (synthetic), caffeic acid (wide distribution in plants), coffee bean, comidendrin (spruce resin, wood liquor wastes), dihydroquercetin (bark of Douglas fir, Jeffrey pine), diphenyl, p-phenylene-diamine ("DPPD," synthetic), eugenol (clove and nutmeg oils), gallic acid (many tannins), methylene blue (synthetic), pimiferin (fruit of osage orange tree), propyl gallate (synthetic), quercetin (rinds of many fruits, as glycosides of bark and leaves of some plants), vanillin (widely in plants, fruit of Vanilla plantifolia).

Ar = aryl group, Et = ethyl or ethyl group, G = glucuronic acid group, Ph = phenyl group, R = alkyl group, X = any substituted group.

Part I: OXIDATION

The liver is the principal site of action for most of these oxidations.

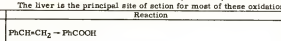
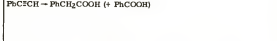
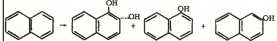
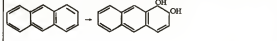
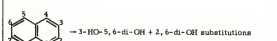
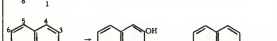
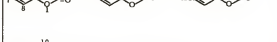
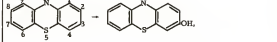
	Substance	Reaction	Products[1]	Remarks
1	Alcohols, primary aliphatic	$RCH_2OH \rightarrow RCHO \rightarrow RCOOH \rightarrow CO_2 + H_2O$	Fatty acids and aldehydes.	Liver principal site of action.
2	Ethyl alcohol	$CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH \rightarrow CO_2 + H_2O$	Acetic acid, acetaldehyde.	Liver principal site of action.
3	2-Ethylhexanol	$C_4H_9CHEtCH_2OH \rightarrow C_4H_9CHEtCOOH \rightarrow C_4H_9CHEtCOOC_6H_9O_6$	2-Ethylhexanoic acid.	Acid forms ester glucuronide.
4	Alcohols, secondary aliphatic	$RR'CHOH \rightarrow RR'CO + RR'CHOC_6H_9O_6$	Ketones.	Partly oxidized, partly conjugated.
5	Isopropyl alcohol	$(CH_3)_2CHOH \rightarrow (CH_3)_2CO$	Acetone	Mostly oxidized.
6	Higher secondary alcohols	Cf Item 4, above.	Ketones.	Conjugated and/or oxidized.
7	Alcohols, tertiary aliphatic	$RR'R''COH \rightarrow RR'R''COC_6H_9O_6$ (principal reaction)	Difficultly oxidized.	Mostly conjugated.
8	Alcohols, primary aromatic	$ArCH_2OH \rightarrow ArCOOH$	Aromatic acids.	
9	Benzyl alcohol	$C_6H_5CH_2OH \rightarrow C_6H_5COOH$	Benzoic acid.	Hippuric acid excreted.
10	Saligenin	$HO\text{-}C_6H_4CH_2OH \rightarrow HOC_6H_4COOH$	Salicylic acid.	Saligenin also directly conjugated.
11	Alcohols, secondary aromatic	$ArCHOHCH_3 \rightarrow ArCOOH + ArCHOGCH_3$	Aromatic acid.	Extensive conjugation as well as oxidation.
12	Methyl phenyl carbinol	$C_6H_5CHOHCH_3 \rightarrow C_6H_5COOH + C_6H_5CHOGCH_3$	Benzoic acid.	Forms glucuronide.
13	Aldehydes, aliphatic	$RCHO \rightarrow RCOOH \rightarrow CO_2 + H_2O$	Fatty acids.	Acid oxidized to CO_2.
14	Formaldehyde	$HCHO \rightarrow HCOOH \rightarrow CO_2 + H_2O$	Formic acid.	Acid oxidized to CO_2.
15	Aldehydes, aromatic	$ArCHO \rightarrow ArCOOH$	Aromatic acids.	
16	Benzaldehyde	$C_6H_5CHO \rightarrow C_6H_5COOH$	Benzoic acid.	Hippuric acid excreted.
17	Hydroxyaldehydes	$HOArCHO \rightarrow HOArCOOH + GOArCHO$	Hydroxyaromatic acid.	Some conjugated aldehyde also formed.
18	Ethers, aromatic	$ArOR \rightarrow HOAr'OR$ or $ArOH$	Phenols.	Formed either by oxidation or oxidative demethylation.
19	Methyl phenyl ether (anisole)	$C_6H_5OCH_3 \rightarrow p\text{-}HOC_6H_4OCH_3$	p-Methoxyphenol.	Oxidation of aromatic ring.
20	p-Nitroanisole	$p\text{-}NO_2C_6H_4OCH_3 \rightarrow p\text{-}NO_2C_6H_4OH + HCHO$	p-Nitrophenol.	Oxidative demethylation.
21	Glycols		Corresponding di- and monocarboxylic acids.	Oxidation not thoroughly studied.
22	Ethylene glycol	$(CH_2OH)_2 \rightarrow (COOH)_2$	Oxalic acid.	Glycol not conjugated with glucuronic acid.
23	2,2-Diethylpropane-1,3 diol	$Et_2C(CH_2OH)_2 \rightarrow Et_2C(CH_2OH)COOH$	α,α-Diethyl-hydracrylic acid.	Diol partly conjugated with glucuronic acid.
24	Ketones, aromatic	$ArCOR \rightarrow ArCOOH + ArCHOHR$	Benzoic or phenylacetic acid	Reduction to carbinols (principal reaction).
25	Acetophenone	$C_6H_5COCH_3 \rightarrow C_6H_5COOH + C_6H_5CHOHCH_3$	Benzoic acid	All acylphenones yield benzoic acid.
26	Benzene	$C_6H_6 \rightarrow C_6H_5OH$ [also o- and p-$C_6H_4(OH)_2$, 1,2,4-$C_6H_4(OH)_3$, muconic acid]	Phenol, polyphenols.	Nearly half eliminated unchanged in expired air.
27	Toluene	$C_6H_5CH_3 \rightarrow C_6H_5COOH$	Benzoic acid.	Excreted as hippuric acid.
28	Xylenes	$C_6H_4(CH_3)_2 \rightarrow C_6H_4(CH_3)COOH$	Toluic acids.	Small amts. of xylenols formed.
29	Mono-substituted benzenes (except alkylbenzenes)	$C_6H_5X \rightarrow p\text{-}HOC_6H_4X$ (plus o- or p-isomer)	p-Substituted phenols (from all types of substituted benzenes),	Also m-phenols or o-phenols according to type.
30	Aniline	$C_6H_5NH_2 \rightarrow p\text{-}HOC_6H_4NH_2 + o\text{-}HOC_6H_4NH_2$	p-Aminophenol.	Some o-aminophenol.
31	Nitrobenzene	$C_6H_5NO_2 \rightarrow p\text{-}HOC_6H_4NO_2 + m\text{-}HOC_6H_4NO_2$	p-Nitrophenol.	Also m-nitrophenol.
32	Polysubstituted benzenes		Phenols.	
33	1,3,5-Trichlorobenzene	$1,3,5\text{-}C_6H_3Cl_3 \rightarrow 1,2,4,6\text{-}C_6H_2(OH)Cl_3$	2,4,6-Trichlorophenol.	
34	Alkylbenzenes		Secondary carbinols + benzoic or phenylacetic acids.	Carbinols excreted as glucuronides; acids as glycine conjugates.
35	Ethyl benzene	$PhCH_2CH_3 \rightarrow PhCOOH + PhCHOHCH_3 + PhCH_2COOH$	Benzoic and phenylacetic acids, methyl phenyl carbinol.	
36	Propylbenzene	$PhCH_2CH_2CH_3 \rightarrow PhCOOH + PhCH_2CHOHCH_3 + PhCHOHCH_2CH_3$	Benzoic acid; benzyl methyl and ethyl phenyl carbinols.	
37	Isopropylbenzene (cumene)	$PhCH(CH_3)_2 \rightarrow PhCOOH + PhCH(CH_3)CH_2OH + PhCH(CH_3)COOH$	Hydratropic acid, hydratropoyl alcohol, benzoic acid.	
38	tert.-Butylbenzene	$Ph(CH_3)_3 \rightarrow PhC(CH_3)_2CH_2OH$	2,2-Dimethyl-2-phenylethanol only	

[1] Other than CO_2 and H_2O.

Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group, Ph = phenyl group; R = alkyl group; X = any substituted group.

Part I: OXIDATION (Continued)

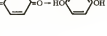
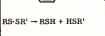
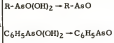
The liver is the principal site of action for most of these oxidations.

	Substance	Reaction	Product[1]	Remarks
	Alkylbenzenes (concluded)			
39	Styrene	$PhCH{=}CH_2 \rightarrow PhCOOH$	Benzoic acid (partly).	Excreted as hippuric acid.
40	Phenylacetylene	$PhC{\equiv}CH \rightarrow PhCH_2COOH$ (+ PhCOOH)	Phenylacetic and some benzoic acid.	Much eliminated unchanged in breath.
41	Polycyclic hydrocarbons		Phenols and trans-1,2-dihydro-1,2-diols.	Free and conjugated.
42	Naphthalene		trans-1,2-Dihydronaphthalene-1,2-diol.	Also 1- and 2-naphthols.
43	Anthracene		1,2-Dihydroanthracene-1,2-diol.	Free and conjugated.
44	Heterocyclic rings		Phenols or hydroxy compounds.	Usually conjugated.
45	Pyridine	 (minor reaction)	3-Pyridinol (trace metabolite).	Major metabolites unknown; N-methylpyridium hydroxide formed in some animals.
46	3-Alkyl pyridines (e.g., nicotinamide)		3-Alkyl-6-ketopyridines.	
47	Quinoline	 → 3-HO-5,6-di-OH + 2,6-di-OH substitutions	3-Quinolinol, 5,6- and 2,6-quinoline-diols.	Conjugated 2-hydroxyquinoline formed in vitro.
48	Coumarin		3- and 7-Hydroxycoumarins.	Conjugated, 3- is principal phenol.
49	3-Substituted coumarins		7-Hydroxycoumarins.	
50	Phenothiazine		3-Hydroxy-3,7-dihydroxyphenothiazine, and 5-oxide.	Free and conjugated.
51	Chlorpromazine (10-dimethylamino-propyl-2-chlorophenothiazine)		5-Oxide.	
52	Indole		3-Hydroxyindole (indoxyl).	
53	3-Substituted indoles		5-Hydroxy derivatives.	
54	Phenols		o- and p-Dihydric phenols (minor reaction).	Major reaction is conjugation.
55	Phenol	$C_6H_5OH \rightarrow$ O- and p-$C_6H_4(OH)_2$; (p- > o-).	Quinol.	Catechol also formed.
56	N-Methylamino compounds, aromatic.	$ArNHCH_3 \rightarrow ArNH_2 + HCHO$.	Aromatic amine + formaldehyde.	Oxidative demethylation.

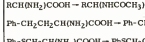
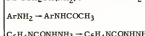
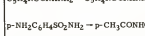
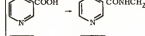
[1] Other than CO_2 and H_2O.

Ar = aryl group, Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

Part II: REDUCTION

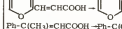
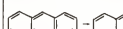
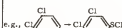
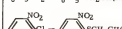
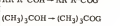
	Substance	Reaction	Products
1	Ketones, aliphatic and aromatic	$RR'CO \rightarrow RR'CHOH$	Secondary alcohols; also excreted conjugated.
2	2-Heptanone	$C_5H_{11}COCH_3 \rightarrow C_6H_{11}CHOHCH_3$	2-Heptanol.
3	Acetophenone	$PhCOCH_3 \rightarrow PhCHOHCH_3$	Methyl phenyl carbinol.
4	Aldehydes, trisubstituted	$RR'R''CCHO \rightarrow RR'R''CCH_2OH$	Primary alcohols.
5	Chloral hydrate	$CCl_3CH(OH)_2 \rightarrow CCl_3CH_2OH$	Trichloroethyl alcohol.
6	p-Quinones (benzoquinone)		Quinols (quinol).
7	2-Methyl-1, 4-naphthoquinone		2-Methyl-1, 4-dihydroxynaphthalene.
8	Nitro compounds, aromatic	$ArNO_2 \rightarrow ArNH_2$	Aromatic amines (partly).
9	Nitrobenzene	$C_6H_5NO_2 \rightarrow p\text{-}HOC_6H_4NH_2$	p-Aminophenol.
10	Trinitrotoluene (2, 4, 6-)		2, 6-Dinitro-4-aminotoluene.
11	Azo compounds	$RN{=}NR' \rightarrow RNH_2 + R'NH_2$	Aromatic amines.
12	Prontosil rubrum		Sulfanilamide, 1, 2, 4-Triaminobenzene.
13	Disulfides	$RS\text{-}SR' \rightarrow RSH + HSR'$	Sulfhydryl compounds.
14	Antabuse	$Et_2NCS\text{-}S\text{-}S\text{-}SCNEt_2 \rightarrow Et_2NCSSH$	Diethyldithiocarbamate.
15	Pentavalent organic arsonic acids	$R\text{-}AsO(OH)_2 \rightarrow R\text{-}AsO$	Trivalent arsenoxides + minor metabolites(?).
16	Phenylarsonic acids	$C_6H_5AsO(OH)_2 \rightarrow C_6H_5AsO$	Phenylarsenoxide. Reduction a minor reaction.

Part III: SYNTHESIS OR CONJUGATION

	Substance	Reaction	End Products	Remarks
		Acylation		
1	Aliphatic primary amines	$RNH_2 + AcCoA \rightarrow RNHCOCH_3 + CoA$	Acetylamines.	Uncommon reaction; deamination main reaction.
2	Glucosamine		N-Acetylglucosamine.	
3	Histamine		Acetylhistamine.	Extent of acetylation varies with species.
4	α-Amino acids	$RCH(NH_2)COOH \rightarrow RCH(NHCOCH_3)COOH$	N-Acetylamino acid.	Occurs in most species with foreign amino-acids
5	γ-Phenyl-α-amino-butyric acid	$Ph\text{-}CH_2CH_2CH(NH_2)COOH \rightarrow Ph\text{-}CH_2CH_2CH(NHCOCH_3)COOH$	γ-Phenyl-α-acetamidobutyric acid.	and d- isomers. Natural amino acids are reversibly acetylated in intermediary metabolism.
6	S-Phenylcysteine	$Ph\text{-}SCH_2CH(NH_2)COOH \rightarrow PhSCH_2CH(NHCOCH_3)COOH$	Phenylmercapturic acid.	
7	Aromatic primary amines	$ArNH_2 \rightarrow ArNHCOCH_3$	Acetylated aromatic amine.	Extent varies with amine; does not occur in dog.
8	Isonicotinic hydrazide	$C_5H_4NCONHNH_2 \rightarrow C_5H_4NCONHNHCOCH_3$	1-Acetyl-2-isonicotinyl hydrazide.	In man, rhesus monkey; not in dog.
9	Sulfanilamide	$p\text{-}NH_2C_6H_4SO_2NH_2 \rightarrow p\text{-}CH_3CONHC_6H_4SO_2NH_2$	N-Acetylsulfanilamide.	In most animals except dog.
		Glycine Conjugation		
10	Aromatic acids	$ArCOOH \rightarrow ArCONHCH_2COOH$	Aroylglycines.	
11	Benzoic acid		Hippuric acid.	
12	α- and β-Naphtholic acids		α- and β-Naphthuric acids.	
13	Nicotinic acid		Nicotinuric acid.	Type: $ArCOOH$. Also substituted benzoic acids. Reaction occurs in mammals, insects, some reptiles, but not in birds.
14	Furoic acid		Furoylglycine (pyromucuric acid).	
15	Thiophene-2-carboxylic acid		Thiphenuric acid.	
16	Substituted acetic acids			Types: $ArCH_2COOH$, $ArCHRCOOH$, $ArCHR'COOH$, and possibly $RR'R''CCOOH$ (some bile acids also form glycine conjugates).
17	Phenylacetic acid	$Ph\text{-}CH_2COOH \rightarrow Ph\text{-}CH_2CONHCH_2COOH$	Phenaceturic acid.	In mammals except man.
18	Indolylacetic acid		Indolylaceturic acid.	
19	Hydratropic acid	$Ph\text{-}CH(CH_3)COOH \rightarrow Ph\text{-}CH(CH_3)CONHCH_2COOH$	Hydratropoylglycine.	
20	Phellandric acid		Phellanduric acid.	

Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

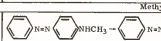
Part III. SYNTHESIS OR CONJUGATION (Continued)

	Substance	Reaction	End Products	Remarks
		Glycine Conjugation (concluded)		
21	β-Substituted acrylic acids.			Type: ArCH=CHCOOH; ArCR=CHCOOH
22	Cinnamic acid	$Ph\text{-}CH{=}CHCOOH \rightarrow Ph\text{-}CH{=}CHCONHCH_2COOH$	Cinnamoylglycine.	
23	2-Furylacrylic acid		Furfuracrylic acid.	
24	β-Methylcinnamic acid	$Ph\text{-}C(CH_3){=}CHCOOH \rightarrow Ph\text{-}C(CH_3){=}CHCONHCH_2COOH$	β-Methylcinnamoylglycine.	
		Glutamine Conjugation		
25	Phenylacetic acid	$Ph\text{-}CH_2COOH \rightarrow Ph\text{-}CH_2CONHCH(COOH)CH_2CH_2CONH_2$	Phenylacetylglutamine.	Occurs in only man and chimpanzee.
		Ornithine Conjugation		
26	Aromatic acids		N,N'-Diaroylornithines (or ornithuric acids).	Occurs only in birds and some reptiles.
27	Benzoic acid (also substituted benzoic acids)	$Ph\text{-}COOH \rightarrow Ph\text{-}CONHCH_2CH_2CH_2CH(COOH)NHCOC_6H_5$	Ornithuric acid.	
28	Furoic acid		Difuroylornithine.	
29	Nicotinic acid		Dinicotinoylornithine.	
30	Phenylacetic acid		Diphenacetylornithine.	Hens.
		Cysteine Conjugation		
31	Aromatic hydrocarbons	$ArH \rightarrow ArSCH_2CH(NHCOCH_3)COOH$	N-Acetyl-S-arylcysteines or mercapturic acids.	Not all polycyclic hydrocarbons form mercapturic acids.
32	Benzene	$C_6H_6 \rightarrow Ph\text{-}SCH_2CH(NHCOCH_3)COOH$	Phenylmercapturic acid.	
33	Naphthalene		1-Naphthylmercapturic acid.	
34	Anthracene		1-Anthrylmercapturic acid.	
35	Halogenated aromatic hydrocarbons		Mercapturic acids.	Tetra- and penta-chlorobenzenes form little if any mercapturic acid.
36	Bromobenzene	$Ph\text{-}Br \rightarrow p\text{-}BrC_6H_4SCH_2CH(NHCOCH_3)COOH$	p-Bromophenylmercapturic acid.	In large amounts.
37	o- and m-Dichlorobenzene	 e.g.,	Dichlorophenylmercapturic acid.	p-Dichlorobenzene is not conjugated.
38	Benzyl chloride	$Ph\text{-}CH_2Cl \rightarrow Ph\text{-}CH_2SCH_2CH(NHCOCH_3)COOH$	Benzylmercapturic acid.	
39	Some chloronitrobenzenes		Mercapturic acids.	Conjugation occurs by replacement of chloro- or nitro-groups.
40	Pentachloronitrobenzene	$C_6Cl_5NO_2 \rightarrow C_6Cl_5SCH_2CH(NHCOCH_3)COOH$	Pentachlorophenylmercapturic acid.	Acetylcysteinyl denitration.
41	2,4-Dichloronitrobenzene		5-Chloro-2-nitrophenylmercapturic acid.	Acetylcysteinyl dechlorination.
		Glycoside Conjugation		
42	Primary alcohols	$RCH_2OH \rightarrow RCH_2OG$	Alkylglucuronides, RCH_2OG.	Minor metabolites; oxidation principal reaction.
43	Ethanol	$CH_3CH_2OH \rightarrow CH_3CH_2OC_6H_9O_6$	Ethyl glucuronide.	Minor metabolite.
44	2,2-Dimethyl-2-phenyl ethanol	$Ph\text{-}C(CH_3)_2CH_2OH \rightarrow Ph\text{-}C(CH_3)_2CH_2OG$	2,2-Dimethyl-2-phenylethylglucuronide.	Major metabolite.
45	Secondary alcohols	$RR'CHOH \rightarrow RR'CHOG$	Alkylglucuronides, $RR'CHOG$.	
46	Pentan-2-ol	$C_5H_7CHOHCH_3 \rightarrow C_5H_7CHOOCH_3$	2-Pentylglucuronide.	
47	Tertiary alcohols	$RR'R''COH \rightarrow RR'R''COG$	Alkylglucuronides, $RR'R''COG$.	Principally conjugation.
48	tert.-Butanol	$(CH_3)_3COH \rightarrow (CH_3)_3COG$	tert.-Butylglucuronide.	
49	Phenols (all types)	$ArOH \rightarrow ArOG$	Arylglucuronides, ArOG.	
50	Phenol		Phenylglucuronide.	
51	Aliphatic acids		Acylglucuronides, RCOOG.	Occurs with α-substituted fatty acids.
52	Diethylacetic acid	$(C_2H_5)_2CHCOOH \rightarrow (C_2H_5)_2CHCOOG$	Diethylacetylglucuronide.	
53	Aromatic amines	$ArNH_2 \rightarrow ArNHG$	N-Glucuronides.	Probable.
54	Phenol	$Ph\text{-}OH \rightarrow Ph\text{-}OC_6H_{11}O_5$ (β-)	β-Phenylglucoside.	Occurs in insects, not in mammals.
55	Imidazolesecetic acid		1-(3)-Ribosylimidazole-4-(5)-acetic acid.	Occurs in rats and mice.

327. DETOXICATION MECHANISMS (Concluded)

Ar = aryl group; Et = ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

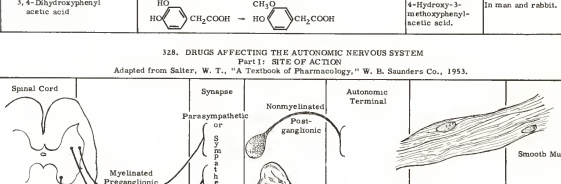
Part III: SYNTHESES OR CONJUGATION (Concluded)

	Substance	Reaction	End Products	Remarks
		Ethereal Sulfate Formation		
56	Phenols	$Ph\text{-}OH \rightarrow PhOSO_3H$	Arylsulfuric acids.	Occurs with phenols of pK_a 6–11.
57	Aromatic amines	$ArNH_2 \rightarrow ArNHSO_3H$	Sulfamates.	Probable.
		Thiocyanate Formation		
58	Cyanide ions	$CN^- \rightarrow CNS^-$	Thiocyanate.	Specific for CN^-.
		Methylation		
59	Monomethylaminoazobenzene		Dimethylamino-azobenzene.	Extremely rare.
60	Heterocyclic tertiary nitrogen			Occurs in many species, but only to a slight extent in rabbits.
61	Pyridine		N-Methylpyridium hydroxide.	Occurs in dog, swine, goat, hen, frog, to slight extent in rabbit, not in rat.
62	Quinoline		N-Methylquinolin-ium hydroxide.	
63	3, 5-Diiodo-4-hydroxy-benzoic acid		3, 5-Diiodo-4-methoxybenzoic acid.	In man only.
64	3, 4-Dihydroxyphenyl acetic acid		4-Hydroxy-3-methoxyphenyl-acetic acid.	In man and rabbit.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM

Part I: SITE OF ACTION

Adapted from Salter, W. T., "A Textbook of Pharmacology," W. B. Saunders Co., 1953.



	Structure					
	Preganglionic Cell Body	Preganglionic Fiber	Preganglionic Fiber Terminal To Ganglion Cell	Ganglion Cell and Postganglionic Fiber	Postganglionic Fiber Terminal to Receptor Substance	Receptor Substance	Effector Substance
1			Acetylcholine	Mediator	Acetylcholine or sympathin.		
2	Apomorphine.		Eserine, DFP, HETP, TEPP.	Stimulant Drugs Acting on ganglia: Nicotine (trace), acetylcholine, mecholyl.	Parasympathetic: Neostigmine, eserine, DFP, HETP, TEPP.	Muscarine, arecoline, pilocarpine, acetylcholine, methacholine, carbamoylcholine (eserine).	
3					Sympathetic: Ephedrine	Epinephrine, arterenol, ephedrine, amphetamine.	(Ephedrine, amphetamine).
4				Inhibitory or Blocking Drugs TEAC, C_5, C_5, nicotine (excess), sympathomimetics, (banthine, atropine), acetylcholine (excess).	Parasympathetic:	Atropine, hyoscine, banthine.	(Atropine).
5					Sympathetic:	Dibenamine, ergot, benzodioxane, yohimbine.	(Ergot), benzodioxane.

The use of trade names in this table is for informative purposes only and in no way implies endorsement by The National Academy of Sciences -- The National Research Council.

Part II: CHEMISTRY AND TOXICOLOGY

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

	Common or Trade Name, Synonyms	Chemical Name	Structure	Pressor Activity (Epinephrine Equivalent)	Toxicity mg/kg				
					Animal (Dose)	PO	SC	IP	IM	IV
			Sympathomimetic Drugs							
1	Amphetamine, (Benzedrine)	dl-a-Methylphenethylamine		1:100-1:300	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		42 11 39-165	75 30	10	10
2	Phenylpropylmethyl-amine, (Vonedrine)	dl-N, β-Dimethylphen-ethylamine		1:600	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		540 205 850	 165	220	72
3	d-Desoxyephedrine HCl, (Pervitin)	d-N, a-Dimethylphen-ethylamine hydrochloride		1:100-1:300	Mouse (LD_{50}) Rat (MLD)			75 17		
4	Mephentermine	N, a, a-Trimethylphen-ethylamine sulfate								
5	Mydriatine, (dl-Nor-ephedrine HCl)	a-[1-Aminoethyl) benzyl alcohol hydrochloride		1:60-1:300	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		600 255 380-860	300 160	320	50
6	l-Ephedrine	l-Phenyl-2-methylamino-propanol		1:100-1:300	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		600 165 320-550	325 165	175	60
7	l-N-Ethylephedrine HCl, (Nethamine HCl)	2-Methylethylamino-1-phenyl-1-propanol hydrochloride		Hypotensor						
8	Hydroxyamphetamine, (Paredrine)	dl-p-Hydroxy-a-a-methyl-phenethylamine		1:50-1:100	Guinea pig (LD_{50}) Mouse (LD_{50})		180	 430		
9	p-(2-Methylamino-propyl)-phenol, (Veritol)	p-Hydroxy-N, a-dimethyl-phenethylamine		1:30-1:250	Rat (LD_{50})			100		
10	Synephrin tartrate, (Sympatol)	p-Hydroxyphenolmethyl-aminoethanol tartrate		1:116	Mouse (MLD) Rabbit (MLD)		700-800			65 50
11	Phenylephrine HCl, (Neo-Synephrine HCl)	1-m-Hydroxy-a-(methyl-aminomethyl) benzyl alcohol		1:56	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		2.2 22 27-33	330 17	7.2	0. 5
12	Methoxyphenamine HCl, (Orthoxine HCl)	β-(o-Methoxyphenyl) iso-propylmethylamine hydrochloride		1:1000	Rat (LD_{50})					6.0
13	Epinine HCl	3, 4-Dihydroxyphenyl-ethylmethylamine hydro-chloride		1:10-1:12						
14	l-Arterenol, (l-Nor-epinephrine; l-Noradrenaline)	l-a-(Aminomethyl)-3, 4-dihydroxybenzyl alcohol		1:2-1:5	Mouse (LD_{50}) Rat (LD_{50})					5. 0. 10[1] 0. 10; 1. 40[1]
15	3, 4-Dihydroxynoreph-edrine HCl, (Cobe-frine HCl)	3, 4-Dihydroxyphenylpro-panolamine hydrochlo-ride		1:4-1:12	Rabbit (MLD) Rat (LD_{50})					11 8
17	Butenedrine HCl	a-(l-Aminopropyl) proto-catechuyl alcohol hydrochloride		Hypotensor	Mouse (LD_{50})					117
17	Epinephrine, (Adre-nsaline)	3, 4-Dihydroxy-a-(methyl-aminomethyl) benzyl alcohol		1:1	Mouse (LD_{50}) Rat (LD_{50})			13[2]		2. 74; 50[3] 0. 04; 0. 80[3]
18	N-Methylepinephrine, (N-Methyladrenaline; Methadren)	a-(Dimethylaminomethyl) protocatechuyl alcohol		1:10-1:25	Mouse Rabbit		250			40
19	Isopropylarterenol, (Isuprel)	a-(Isopropylaminomethyl) protocatechuyl alcohol		Hypotensor	Mouse (LD_{50})			450		83
20	Methoxamine HCl, (Vasoxyl HCl)	2-Amino-1-(2, 5-dimeth-oxyphenyl)-1-propanol hydrochloride			Mouse (LD_{50})	92				
21	Naphazoline HCl, (Privine HCl)	2-[1-Naphthylmethyl) imidazoline hydrochlo-ride			Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		170 0. 95 325-538	 50	0. 95	0. 8
22	N-1-Dimethylhexyl-amine, (Gemethyl)	2-Methylaminoheptane								
23	Tuaminoheptane, (Tuamine)	1-Methylhexylamine		1:320	Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})		115 130 135-169	75 34	85	22
24	Octin	6-Methylamino-2-methylheptene			Dog (LD) Mouse (LD 50) Rabbit (LD 50)	148	76. 3 171 101			25. 8 17. 5 17. 6
25	N, a-Dimethylcyclo-hexaneethylamine, (Benzedrex)	N-Methyl-β-cyclohexyl-isopropylamine		1:333-1:500	Guinea pig (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})			85 80- 90 65-75		
26	Cyclopentamine HCl, (Clopane HCl)	N, a-Dimethylcyclo-pentaneethylamine hydrochloride								

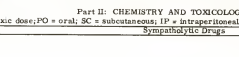
/1/Second value for d-arterenol. /2/ l-epinephrine. /3/ d-epinephrine.

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Part II: CHEMISTRY AND TOXICOLOGY (Continued)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

Sympatholytic Drugs

Common Name	Structure	Adrenolytic Action: Rabbit Uterus	Adrenolytic Action: Guinea Pig Seminal Vesicle	Adrenolytic Action: Epinephrine Hypertensive Reversal, Dog mg/kg, IV	Toxicity: Species (Route)	Toxicity: LD_{50}[4] mg/kg
		Isolated (Ergotamines[1])				
For lines 27-31: lysergic acid, [R], d-proline, and [R'] are joined in amide linkages.						
	R' / R2 / R / R1					
27 Ergocornine	l- Valine / -CH(CH3)CH3 / Dimethylpyruvic acid / -CH(CH3)CH3	0.5	2		Rabbit(IV)	1.17
28 Ergocristine	l- Phenylalanine / -CH2-C6H5 / Dimethylpyruvic acid / -CH(CH3)CH3	1.0	4		Rabbit (IV)	2.17
29 Ergocryptine	l- Leucine / -CH2-CH(CH3)CH3 / Dimethylpyruvic acid / -CH(CH3)CH3	1.5	4		Rabbit(IV)	1.05
30 Ergotoxine	l- Phenylalanine / -CH2-C6H5 / Dimethylpyruvic acid / -CH(CH3)CH3					
31 Ergotamine	l- Phenylalanine / -CH2-C6H5 / Pyruvic acid / -NH2					
32 Ergonovine	Lysergic acid-NH-CHCH2OH (CH3)	1	1	0.2-0.5	Mouse (IV) Rabbit (IV) Rat (IV)	62 3.55 80
33 Dihydroergotamine[5]	5,10-dihydro derivative of ergotamine	2.25	7	0.2-0.5	Mouse (IV) Rabbit (IV) Rat (IV)	118 25 110
34 Dihydroergocornine	5,10-dihydro derivative of ergocornine — methane sulfonate "Hydergine"	2.5	25		Rabbit (IV)	35
35 Dihydroergocristine	5,10-dihydro derivative of ergocristine	3.5	35		Rabbit (IV)	27
36 Dihydroergocryptine	5,10-dihydro derivative of ergocryptine	5.0	35		Rabbit (IV)	19
	Chemical Name / Structure					
37 Yohimbine (Quebrachine; Corynine; Aphrodine)	(Chief alkaloid of Corynanthe johimbe; 10 isomers known) 	1:200		1	Guinea pig (IP) Mouse (PO) Mouse (IV)	42(TD) (86.7-1000) (TD) 16 (TD)
38 N-(2-Chloroethyl)-dibenzylamine HCl (Dibenamine HCl)	β-Chloroethyldibenzylamine hydrochloride 			10-20	Cat (IV) Mouse (SC) Mouse (IP) Mouse (IV)	35 400-500 75-100 50
39 Benzazoline HCl, (Priscoline HCl)	2-Benzyl-4,5-imidazoline hydrochloride 			10		
40 Piperoxan HCl, (933F)	2-(1-Piperidylmethyl)-1,4-benzodioxan hydrochloride 	1:100			Mouse (IP)	180 (TD)
41 Prosympal, (883F)	2-(Diethylaminoethyl)-benzodioxan 	1:200		1	Frog (SC) Guinea pig (SC) Mouse (SC) Rabbit (SC) Rabbit (IV)	250 (TD) 400 (TD) 500 (TD) 300 (TD) 30 (TD)
42 Regitine, (C7337)	2-(N'-p-tolyl-N'-m-hydroxyphenylaminoethyl) imidazoline 				Mouse (PO) Rabbit (PO) Rat (PO)	750 2000 1250

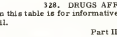
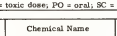
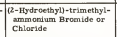
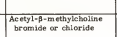
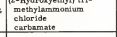
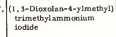
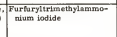
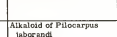
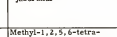
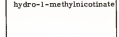
/4/ Unless otherwise indicated in parentheses. /5/ D H. E. 45.

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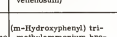
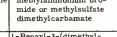
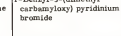
Part II; CHEMISTRY AND TOXICOLOGY (Continued)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

Parasympathomimetic Drugs

	Common or Trade Name, Synonyms	Chemical Name	Structure	Pressor Activity	Toxicity, mg/kg Species (Dose)	PO	SC	IP	IM	IV
43	Acetylcholine, (Fragmoline; Acecoline)	(2-Hydroethyl)-trimethylammonium Bromide or Chloride		1	Mouse (TD) Rabbit (TD) Rat (TD)	3000 2500	170 250			20 0.15
44	Methacholine, (Mecholyl)	Acetyl-β-methylcholine bromide or chloride		1	Mouse (TD)	1100				
45	Carbachol, (Choline chloride carbamate; carbamoylcholine chloride	(2-Hydroxyethyl) trimethylammonium chloride carbamate		5-10 (Dog); 1 (Rabbit)	Dog (TD) Guinea pig (TD) Mouse (TD)	 25	0.1 0.075 0.5			 0.5
46	Vasodilatateur 2249F, (Dilvasene)	(1,3-Dioxolan-4-ylmethyl) trimethylammonium iodide		0.5-0.2	Guinea pig (TD) Mouse (TD) Rat (TD)	 300	5 35 25			 2.5
47	Furtrethonium Iodide, (Furmethide Iodide)	Furfuryltrimethylammonium iodide			Rat (LD_{50})		90			
48	Muscarine	Alkaloid of Amanita muscarina			Cat (TD)		2-4			
49	Pilocarpine	Alkaloid of Pilocarpus jaborandi								
50	Arecoline	Methyl-1,2,5,6-tetrahydro-1-methylnicotinate			Mouse (TD)		65			
51	Physostigmine[6]. (Eserine)	Main alkaloid of Calabar bean (Physostigma venenosum)			Cat (LD_{50}) Mouse (LD_{50}) Rabbit (LD_{50})	 3	 0.75 3			0.68 0.45 0.5-0.8
52	Neostigmine Bromide[6], (Prostigmine Bromide)	(m-Hydroxyphenyl) trimethylammonium bromide or methylsulfate dimethylcarbamate			Mouse (LD_{50}) Rabbit (LD_{50})	12-16	1 0.5-0.75			0.30 0.25
53	Benspyrinium Bromide[6], (Stigmonene Bromide)	1-Benzyl-3-(dimethylcarbamyloxy) pyridinium bromide								
54	DFP[6]	Diisopropyl fluorophosphate			Cat (LD_{50}) Dog (LD_{50}) Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})	 36.8 9.78	 3.71		 1.82	1.63 3.43 0.34

Parasympatholytic Drugs

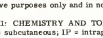
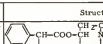
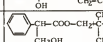
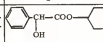
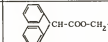
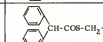
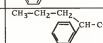
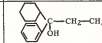
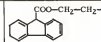
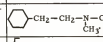
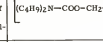
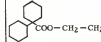
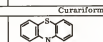
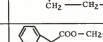
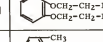
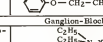
	Common or Trade Name, Synonyms	Chemical Name	Structure	Toxicity, mg/kg Species (Dose)	PO	SC	IP	IM	IV
55	Atropine, (dl-Hyoscyamine)	dl-Tropyltropate		Cat (TD) Dog (TD) Guinea pig (TD) Mouse (TD) Mouse (LD_{50}) Rabbit (TD) Rat (TD) Rat (LD_{50})	 796 400-1500 	125-150 175-200 300-400 200-500 700-750 	 215 280		50-100 70 68-90.8 41
56	Scopolamine, (Hyoscine)								
57	Genatropine	Atropine-N-oxide		Dog (TD)					200

/6/ Inhibitor of cholinesterase.

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Part II: CHEMISTRY AND TOXICOLOGY (Concluded)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

	Common or Trade Name, Synonyms	Chemical Name	Structure	Toxicity, mg/Kg				
				Species (Dose)	PO	SC	IP	IM	IV
58	Homatropine, (Mydriasine)	Mandelyltropeine (methyl-bromide)		Guinea pig (LD_{50}) Mouse (LD_{50}) Rat(LD_{50})	1000 1400 1200	650 800	120 60 82		
59	Amprotropine Phosphate, (Syntropan)	3-Diethylamino-2,2-dimethylpropyltropate phosphate		Mouse (LD)		1600			70
60	Eucatropine HCl	4-Hydroxy-1,2,2,6-tetramethylpiperidine mandelate hydrochloride							
61	Trasentine	2-Diethylaminoethyl α-phenyl cyclohexane-acetate HCl		Mouse (LD_{50}) Rat (LD_{50})	780		220 250		27 32
62	Trocinate	β-Diethylaminoethyl-diphenylthioacetate hydrochloride							
63	Propivane, (117RP)	2-Diethylaminoethyl-propylphenylacetate hydrochloride							
64	Artane Trihexyl-phenidyl	α-Cyclohexyl-α-phenyl-1-piperidinepropanol hydrochloride		Mouse (LD_{50}) Rat (LD_{50})			162 195		39 30
65	Pavatrine HCl	2-Diethylaminoethyl 9-fluorenecarboxylate hydrochloride		Mouse (LD)			320		
66	Cyverine HCl	Methyl-bis (β-cyclohexyl-ethyl) amine hydrochloride							
67	Dibutoline Sulfate, (Dibuline Sulfate)	Bis [(dibutylcarbamate) of ethyl (2-hydroxyethyl) dimethylammonium] sulfate		Rat (LD_{50})			22		
68	Dicyclomine HCl, (Bentyl)	1-Cyclohexylhexahydrobenzoic acid, β-diethylaminoethyl ester hydrochloride							
			Curariform Drugs						
69	Diethazine Base, or HCl, (Diparcol Base or HCl, 2987RP)	10-(2-Diethylaminoethyl) phenothiazine		Mouse (LD_{50}) Rabbit (LD_{50})		450 200			45 25
70	Caramiphen HCl, (Parpanit)	1-Phenylcyclopentane-carboxylic acid 2-diethylaminoethyl ester hydrochloride		Cat (LD_{50}) Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})	390		222.3 209		45.1 24.5
71	Gallamine Triethiodide, (Flaxedil; 3697RP; 2559F)	[ν-Phenenyltris (oxyethylene)]-trus [triethylammonium iodide]		Dog (LD_{50}) Mouse (LD_{50}) Rabbit (LD_{50}) Rat (LD_{50})	425 100	15 25		2.3	0.8 4.5 24.5 5.5
72	Myanesin	3-o-Toloxy-1,2-propanediol		Mouse (LD_{50})			560		
			Ganglion-Blocking Drugs						
73	T. E. A. Chloride, (Etamon); TEAB	Tetraethylammonium bromide or chloride		Dog (LD_{50}) Mouse (LD_{50}) Rat (LD_{50})	900 2630		65	58 110	36.4 56.3
74	Hexamethonium Bromide (Hexameton)	Hexamethylenebis [trimethylammonium bromide]							

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Part III: CLINICAL APPLICATIONS

Numbers in brackets refer to drugs listed in Part II.

Drug Number		Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration[1]
			Sympathomimetic Drugs		
1	[1]	CNS stimulant in narcolepsy, certain depressive conditions, post-encephalitic parkinsonism.	May produce overstimulation, restlessness, insomnia, G.I. upset, chills; collapse and syncope may follow overdosage. Preliminary small test dosages obviate hypertensive reactions or cardiovascular disease.	Anxiety, hyperexcitability or restlessness	PO.
2	[2]	Nasal decongestant.			TOP.
3	[3]	CNS stimulant.	Euphoria, tachycardia, hypertension. Hypersensitivity may cause headache, irritability, vertigo, insomnia and collapse.	Hypertension, heart diseases, or thyrotoxicosis.	PO.
4	[4]	In severe hypotensive states; cardiac and general surgery, spinal anesthesia.		Peripheral vascular collapse.	IV, IM.
5	[5]	Bronchial dilation; nasal vasoconstriction.	Hypertension, tachycardia, and nervous excitation.	Severe hypertension or cardiac disease, thyrotoxicosis.	PO, TOP.
6	[6]	In asthma and allergic disorders; to increase blood pressure; locally, to shrink mucosa of nose; treatment of syncope due to complete heart block.	Nervous insomnia, tachycardia and cardiac consciousness, sweating, headache, hypertension, anxiety.	Thyrotoxicosis, heart disease, hypertension.	PO, IM, SC, TOP.
7	[7]	In bronchial asthma, allergic manifestations; vasomotor rhinitis.	Insomnia; nausea.	Diabetes, severe cardiovascular diseases, markedhyperthyroidism.	PO.
8	[8]	Vasoconstrictor; in postural hypotension, carotid sinus syndrome, nasal decongestion.	Nervous system stimulation, hypertension.	Severe hypertension, cardiac disease, or glaucoma.	PO, TOP.
9	[9]	In hypotension; for pupil dilatation.	Nervous system stimulation, hypertension.	Severe hypertension, cardiac disease.	
10	[10]	Hypertensive in mild collapse caused by falling peripheral blood flow.		Cardiac disease, diabetes, or thyroid disorders.	PO.
11	[11]	In paroxysmal tachycardia, shock, and shock-like states.	Tingling or coloring of skin; "fullness" of the head; transient precordial pain; hyperthyroidism; certain cardiac conditions; hypertension in the aged.		PO, TOP.
12	[12]	In bronchial asthma, acute urticaria, G.I. allergy.	Mild nervous excitation; nausea; hypotension; slight drop in systolic blood pressure, more pronounced in those with hypertension.	Advanced cardiac disease or hypotension.	PO.
13	[13]	Nasal vasoconstrictor.	Tachycardia, hypertension, nervous excitation.	Thyrotoxicosis.	TOP.
14	[14]	In acute hypotensive states, trauma, central vasomotor depression, hemorrhage.	Hypertensive and arteriosclerotic disease.	Use of cyclopropane anesthesia or myocardial ischemia.	IV.
15	[15]	Vasoconstrictor, particularly with local anesthetic.	Comparable to epinephrine (see [17]).		
16	[16]	In bronchial asthmatic paroxysms.		Hypersensitivity to "sympathomimetic amines."	IV, SC.
17	[17]	In asthma, hay fever, acute allergic states, shock; vasoconstrictor applied topically or with local anesthetic.	Anxiety, palpitation, vertigo, headache; acute elevation of blood pressure and vasomotor collapse may occur.	Thyrotoxicosis, cardiac disease, or cerebral arteriosclerosis; cyclopropane or ether anesthesia.	IM, SC, TOP.
18	[18]	Hyperglycemic with local anesthetic.	Hypertension, nervous excitation.	Severe hypertension, cardiac disease.	
19	[19]	Vasoconstrictor; in asthma, allergic states.	Acute hypertension, nervous excitation, palpitations, tachycardia.	Thyrotoxicosis, severe cardiac disease.	SL, IH.
20	[20]	In hypotension, post-operative collapse.			IM.
21	[21]	Nasal vasoconstrictor. As effective as epinephrine but more prolonged action.	Overdose may cause drowsiness, tachycardia, hypertension.	Thyrotoxicosis, severe hypertension, cardiac disease.	TOP.
22	[22]	In hypotension produced by spinal anesthesia.	Hypertension, nervous excitation, headache, dizziness, tachycardia, palpitations.	Thyrotoxicosis, cardiac disease.	IV, IM.
23	[23]	In rhinitis and allergic conditions.			TOP, IH.
24	[24]	Antispasmodic, in vesical and ureteral spasms.	Dizziness, headache.	G.I. obstruction.	PO, IV, SC.
25	[25]	Shrink nasal mucosa. Lacks centrally stimulating properties of amphetamine.			IH.
26	[26]	Nasal decongestant.	Overdose may cause rise in blood pressure, nervousness, occasional nausea, dizziness.		TOP, IH.
			Sympatholytic Drugs		
27	[27, 28, 29]	Peripheral vascular disorders; hypotensive agent.			
28	[30]	Oxytocic.	Hypertension, collapae, colic, nausea, vomiting.	Pregnancy, serious cardiac disease.	
29	[31]	Oxytocic; in migraine.	Hypertension, tachycardia, vomiting. Chronic reactions: gangrene of digits; mental confusion.	Pregnancy, early stages of labor; peripheral vascular disease; diseases of liver, kidneys.	SC, SL.
30	[32]	Oxytocic; in migraine.	G. I. disturbances, hypertension, tachycardia, tremor, excitement, convulsions, exophthalmus (?).	Pregnancy, serious cardiac disease.	

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; Mi = miotic; REC = rectally.

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Part III: CLINICAL APPLICATIONS (Continued)

Numbers in brackets refer to drugs listed in Part II.

	Drug Number	Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration[1]
31	[33]	In migraine.	Nausea, vomiting, weakness, cardiac irregularity.	Pregnancy; peripheral vascular disease; diseases of the liver, kidneys.	IV, IM, SC.
32	[34, 35, 36]	Clinically used for adrenergic blocking and peripheral vasodilatation in peripheral vascular diseases.	Hypotension, kidney injury.	Hypotension.	IM.
33	[37]	Formerly: aphrodesiac, local anesthetic, mydriatic.	Hypotension, kidney injury.	Renal disease.	
34	[38]	In Raynaud's disease, erythromelalgia, causalgia, hypertension, pheochromocytoma.	Usually: postural hypotension; occasionally: nausea, diarrhea, mental confusion.	Arteriosclerosis.	
35	[39]	Vasodilator; in peripheral disease.	Possible peptic ulcer or gastritis; may cause transient syncope.		IV, IM, SC.
36	[40]	Diagnostic agent: detection of epinephrine-producing tumors.	Tachycardia, palpitation, flushing; cold, clammy extremities; hypernoia, nervousness, mild headache, fright, dizziness.		IV.
37	[41]	Sympatholytic vasodilator; analgesic; angors.	Cardiac, digestive disturbances; sedation; bronchitis.		PO.
38	[42]	Diagnostic agent; pheochromocytoma. In vascular disease, hypertensive emergencies.			PO, IV, IM.
			Parasympathomimetic Drugs		
39	[43]	In peripheral vascular diseases, attacks of paroxysmal tachycardia, hypertension, intestinal or bladder stony (post-operative), spasmic occlusion of retinal artery.	Flushing, sweating, vertigo, marked salivation, nausea, vomiting.		IV, IM, SC.
40	[44]	In auricular paroxysmal tachycardia, chronic ulcers, Raynaud's disease, low peripheral blood circulation.	Hypotension; cardiac slowing or arrest.	Allergy, asthma, hyperthyroidism; recent coronary occlusion or severe illness. Never administered IV or IM.	PO, SC, ION.
41	[45]	In urinary retention, post-operative abdominal distension, peripheral vascular diseases (vasospasm), threatened gangrene. Veterinary uses.	Flushing, abdominal pain, vomiturition, headache, asthmatic attacks. Counteraction by atropine.	Asthma or allergic patients suspected of latent asthma. Never administered IV or IM.	PO, SC, TOP, (MI).
42	[46]	Vasodilator; in hypotension, peripheral vascular (Raynaud's) disease.	Flushing, sweating, salivation. Counteraction by atropine.	Never administered IV.	PO, TOP (MI).
43	[47]	In bladder stony, glaucoma.	Cystitis.	Mechanical obstruction of bladder. Never administered IV.	PO, SC.
44	[48]	Experimental pharmacology.	Salivation; lacrimation; vomiting; profuse diarrhea; cardiac slowing; collapse; may progress to convulsions, coma and death in few hours.		
45	[49]	Miotic; in glaucoma, atropine poisoning. Formerly: to increase sweating.	Sweating, salivation, cardiac irregularities, pulmonary edema, increased G.I. motility.	Asthma; pulmonary, cardiac disease.	TOP(MI), SC.
46	[50]	Miotic; in glaucoma.	Cardiac slowing, salivation and miosis.		TOP(MI).
47	[51]	Miotic; in glaucoma; in stimulation of G.I. or bladder activity; myasthenia gravis distension or atony of intestines.	Salivation, lacrimation, tremor and depression of cardiorespiratory system.	Asthma.	IM, SC, TOP.
48	[52]	In glaucoma, atony of G.I. tract and bladder, myasthenia gravis, muscular spasms in poliomyelitis.	Salivation, lacrimation, nervous excitation and depression of cardiorespiratory system.	Asthma or mechanical obstruction of intestines.	PO, IM, SC.
49	[53]	In atony of G.I. tract and bladder, myasthenia gravis, migraine, tachycardia, muscular spasms in poliomyelitis.	Asthma.	Asthma or mechanical obstruction of intestines.	PO, IM.
50	[54]	In glaucoma.	Blurred vision, pain in eyes and brow, ciliary spasm and pericorneal injection. Orally: nausea, vomiting and diarrhea. Systemic administration: prolonged salivation, lacrimation, intestinal cramps, shock, collapse.	Never administered systemically.	TOP.
			Parasympatholytic Drugs		
51	[55a]	Symptomatic treatment of post-encephalitic parkinsonism and paralysis agitans; cardio- and pyloro-spasm; mydriasis and cycloplegia; suppression of excessive salivation; syncope resulting from carotid sinus hypersensitivity or cardiac block.	Dryness of mouth, blurred vision, persistent cycloplegia, tachycardia, excitement and dermatitis.	Glaucoma, corneal ulcer.	PO, IM, SC. TOP.
52	[56]	Hypnotic and sedative. Locally: as substitute for atropine in ophthalmology.	Thirst, dryness of mouth, dilatation of pupil, tachycardia, delirium, ataxia and muscular weakness.	Glaucoma.	PO, SC, TOP.
53	[57]	G.I. disturbances.	Similar to but less toxic than atropine sulfate. Cf 51 [55].		
54	[58]	Mydriatic, cycloplegic.	Similar to but less toxic than atropine sulfate. Cf 51 [55].	Glaucoma	TOP.

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; MI = miotic; REC = rectally. /2/ As atropine sulfate. /3/ As homatropine hydrobromide.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Concluded)

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Part III: CLINICAL APPLICATIONS (Concluded)

Numbers in brackets refer to drugs listed in Part II.

	Drug Number	Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration[1]
55	[59]	Antispasmodic, for smooth muscle; in encephalitic parkinsonism.	Overdosage: may cause convulsions.		PO, IM, SC.
56	[60]	Mydriatic.		Glaucoma	TOP.
57	[61]	Antispasmodic.	Tachycardia, restlessness and nervous excitation.	Glaucoma.	PO, IM, REC.
58	[62]	Antispasmodic, for smooth muscle.	All the advantages of atropine sulfate, none of the disadvantages. Cf 51 [55].		PO.
59	[63]	Antispasmodic, for G. I. and urogenital disorders.	Ten times less toxic than atropine sulfate. Cf 51 [55].		PO, SC, REC.
60	[64]	Parkinsonism.	Blurring of vision, nausea, dryness of mouth, dizziness, "fullness" in head, agitation, confusion.	Glaucoma.	PO.
61	[65]	Antispasmodic.	Tachycardia, nervous excitability.	Glaucoma.	PO.
62	[66]	In pylorospasm, colitis.	Tachycardia, restlessness and nervous excitability.	Glaucoma.	
63	[67]	In G. I., urogenital, biliary spasm; mydriatic; cycloplegic.	Dryness of mouth, mydriasis, moderate hypotension.	Glaucoma.	TOP.
64	[68]	Antispasmodic,for smooth muscle.	Therapeutic dosages: virtually without pupillary,secretory,and cardiac effects of atropine sulfate. Cf 51 [55].		PO.
			Curariform Drugs		
65	[70]	In parkinsonism, muscular spasm, tremor.			
66	[71]	For muscular relaxation.	Neostigmine bromide (Cf 52 [56]) should be available.		
67	[72]	Depression of reflex excitability in such conditions as hemiplagia, paraplegia.	Paralysis.	Myasthenia gravis.	
			Ganglion-blocking Drugs		
68	[73]	Bromide: diagnostic and therapeutic in peripheral vascular affections; diagnostic in hypertension. Chloride: peripheral vascular disorders and arteriosclerosis; diagnostic in hypertension.	Bromide: hypotension. Chloride: reduction of blood pressure, disturbance of accommodation.	Bromide: severe cerebral or cardiac vascular occlusive disorders. Chloride: severe coronary heart disease or cerebral vascular arterial disease.	IV, IM.
69	[74]	ANS blocking agent.			

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; MI = miotic; REC = rectally.

329. EQUIVALENT ANESTHETIC EFFECTS OF GASES; INTACT ANIMALS AND ISOLATED EXCITABLE TISSUES

	Gas	ED_{50}[1]	Blockade[2]	Concentration of Gas in Non-aqueous Phase[3] (x 10^{-4} mole fraction)
		atm		
1	Helium	163		125
2	Nitrogen	18		80
3	Argon	12.6	340	111
4	Methane	2.9	110	60
5	Sulfur hexafluoride	1.87	None	41

	Gas	ED_{50}[1]	Blockade[2]	Concentration of Gas in Non-aqueous Phase[3] (x 10^{-4} mole fraction)
		atm		
6	Krypton	1.8		47
7	Xenon	0.51	12	49
8	Nitrous oxide	0.58	13	66
9	Ethylene	0.47	12	58
10	Cyclopropane	0.045	1.9	

/1/ The partial pressure required to abolish the M.E.C. response to electroshock, in 50% of a large group of mice. /2/ The partial pressure required to abolish reversibly the impulse transmission in isolated rat sciatic nerve. /3/ ED_{50} times mole fraction in benzene at 1 atmosphere.

330. ANESTHESIA, STAGES AND PLANES: MAN

	Designation	Characteristics	General Signs	Drug
1	Stage I (Analgesia'	Senses benumbed; consciousness retained.	Appearance and feeling of well-being. Sense of pain diminished.	All drugs that will produce surgical anesthesia, stage III.
2	Stage II (Delirium)	Consciousness lost; respiration irregular; movement of skeletal muscles probable.	Eyeballs move from side to side, or strabismus may be present.	All drugs that will produce surgical anesthesia, stage III.
3	Stage III (Surgical anesthesia) Plane 1	Swallowing reflex abolished; muscle relaxation is minimal; respiration regular and even.	Eyeballs moving, or strabismus is present. Pupils are of pre-anesthetic size. Eyelid reflex is abolished.	Ethylene, nitrous oxide.
4	Plane 2	Muscle relaxation increased. Intercostal musculature still active in respiration (inspiration). Movements of diaphragm are of normal range. Respirations are regular and even.	Eyeballs are fixed in mid-line.	Chloroform, cyclopropane, di-vinyl ether, ether, ethyl chloride, morphine, pentothal, trichlorethylene.
5	Plane 3	Muscle relaxation further increased and suitable for intra-abdominal surgery. Inspirations are quickened and shortened. Expirations and the inter-respiratory pause are more prolonged.	Eyeballs are fixed in mid-line. Pupils are slightly larger than pre-anesthetic. The light reflex is present but sluggish.	All drugs as in plane 2.
6	Plane 4	Skeletal muscle relaxation is complete. Bronchial (cough) reflexes are dulled. Respiration becomes gasping, and is maintained entirely by the diaphragm. The expiratory phase is further prolonged. Cyanosis may be present. Blood and pulse pressure fall, while pulse rate increases.	Pupils are widely dilated and do not react to light. Conjunctivae are glassy.	Same as plane 2.
7	Stage IV (Overdose or respiratory paralysis)	Cessation of respiration. Extreme relaxation of skeletal musculature. Death in few minutes if respiration not restored.	Eyes fixed in mid-line. Pupils dilated and not reactive to light.	

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	Drug	Animal[1]	Neuromuscular Blocking Potency mg(cation)/kg	LD_{50} mg(cation)/kg	Antagonist or Antidote	Other Effects
1	Decamethylene-1, 10-bis-trimethyl-ammonium dibalide (Decamethonium	Man	0.02-0.025		Hexa- or pentamethonium.	Cardiovascular.
2	halide; C.10; Eulissin; Syncurine)	Cat	0.015-0.018		Hexa- or pentamethonium, stilbazolinium salts.	
3	$N(CH_3)_3$	Monkey	0.125		Hexa- or pentamethonium.	
4	|	Mouse	0.35	0.4-0.5		
5	$[CH_2]_{10}$ -2X	Rabbit	0.04-0.09		Hexa- or pentamethonium.	Anticholinesterase; muscarinic.
6	|	Rat	1.25	1.5		
7	$N(CH_3)_3$	Chick	0.025			
8		Frog[2]	5.5-6.2	>123	Hexa- or pentamethonium.	Contracture.
9		Man	0.7-1.4			Hypotensive; bradycardia.
10		Cat[3]		1.8-2.7		
11		Dog				Bradycardia.
12	Dihydro-ß-erythrodine	Mouse[3]		8.4	Neostigmine.	
13	$(C_{18}H_{21}NO_3)$	Rabbit[3]		9-18		
14		Rat[3]		207		
15		Frog[2]	0.45			
16		Man	0.45-0.6		Neostigmine, tensilon.	Histamine release; parasympathetic.
17	Triethiodide of 1, 2, 3-tri(diethyl-	Cat	0.3-1.1			
18	aminoethoxy)benzene (Flaxedil;	Dog	0.25	0.5	Tensilon.	
19	Gallamine triethiodide)	Mouse	1.2	1.9-2.7		
20	$C_6H_3[O\text{-}CH_2\text{-}CH_2\text{-}N(C_2H_5)_3]_3 \cdot 3I$	Rabbit	0.2-0.3	0.4	Neostigmine.	
21		Rat		3.3		Histamine release.
22		Frog[2]	6 and 36			
23		Man	0.1		Neostigmine.	Histamine release.
24	Decamethylene bis-[1-(3', 4'-dimeth-	Cat	0.1			Ganglion blocking.
25	oxybenzyl)-6, 7-dimethoxy-2-	Mouse	0.2	0.35		
26	methyl-1, 2, 3, 4-tetrahydroisoquin-	Rabbit	0.02	0.04	Neostigmine.	
27	olinium] dimethosulfate (Laudolissin)	Rat	1.05	1.8		
28	$C_{54}H_{60}N_2O_{12}S_2$	Chick	0.25			
29	2, 5-bis-(3-Diethylaminopropylamino)-	Man	0.06-0.24			Bradycardia, salivation bronchorrhea.
30	benzoquinone-bis-benzyl chloride	Cat[4]	9.5	11.7		
31	(Mytolon chloride; Win 2747; Benzo-	Dog	0.1		Neostigmine.	
32	quinonium chloride)	Mouse[3]	0.5	1.4(0.5 i.v.)		
33	$C_{34}H_{50}N_4O_2Cl_2$	Rabbit	0.025	0.04	Neostigmine.	
34		Rat		1.1		
35	bis-(Trimethylammonium-ethyl)suc-cinate dihalide; Dimethohalide of bis-2-Dimethylaminoethyl succinate	Man	0.1-0.3		Plasmacholinesterase.	Anticholinesterase; nicotinic; initial stimulation of muscular contraction.
36	(Suxamethonium halide; Succinyl-choline; Succinocholine; Scoline;	Cat	0.05-0.1			Nicotinic; initial stimulation of muscular contraction.
37	Brevedil M; Celocurine; Anectine;	Dog	0.1	0.15	Plasmacholinesterase.	Anticholinesterase.
38	Lysthenon; Curacil)	Mouse	0.05-0.1	0.25		
39	$CH_3\text{-}CO\text{-}O\text{-}CH_2\text{-}CH_2\text{-}N(CH_3)_3$	Rabbit	0.1	0.5		
40	| ·2 halide	Sparrow	5.0	10.0		Contracture.
41	$CH_2\text{-}CO\text{-}O\text{-}CH_2\text{-}CH_2\text{-}N(CH_3)_3$	Frog[2]	2.5			Nicotinic; contracture.
42	bis-(Dimethylethylammonium ethyl)suc-cinate dihalide, or Diethohalide of bis-2-dimethylaminoethyl succinate	Man	0.5-13			
43	(Suxethonium halide; Brevedil E; Tachycurine; 362.I.S.; M115; M and B 2210)	Dog	0.08-0.25	0.17	Plasmacholinesterase.	Anticholinesterase.
44	$CH_3\text{-}CO\text{-}O\text{-}CH_2\text{-}CH_2\text{-}N(CH_3)_2C_2H_5$	Rabbit	0.45	0.84		
45	| ·2 halide	Frog[2]	14.0			
	$CH_2\text{-}CO\text{-}O\text{-}CH_2\text{-}CH_2\text{-}N(CH_3)_2C_2H_5$					
46		Man				Histamine release.
47		Cat	0.003-0.018	0.018	Neostigmine.	Ganglion blocking; salivation.
48	Toxiferine I chloride (C-Toxiferine	Dog	0.005			
49	I chloride)	Mouse	0.005-0.009	0.01		
50	$C_{20}H_{23}N_2OCl \cdot 3H_2O$	Rabbit	0.004-0.01	0.007		
51		Frog[2]	0.005-0.013			
52		Man	0.08-0.19			Cardiovascular; histamine release.
53		Cat	0.12-0.23		Neostigmine, tensilon.	Histamine release; ganglion blocking.
54	d-Tubocurarine chloride (Tubarine)	Dog	0.08-0.15	0.38	Tensilon.	Ganglion blocking.
55		Monkey	0.06			
56	$C_{38}H_{44}N_2O_6Cl_2 \cdot 5H_2O$	Mouse	0.06-0.09	0.11-0.15		
57		Rabbit	0.09-0.15	0.165	Neostigmine.	Ganglion blocking.
58		Rat	0.04-0.06	0.08		Histamine release.
59		Chick	0.13			
60		Frog[2]	1.4, 4.1 and 7.5	>20.0	Acetylcholine.	
61		Man	0.027		Tensilon, neostigmine.	
62	d-O, O-Dimethyltubocurarine iodide (Dimethyl ether of d- tubocurarine	Cat	0.02			Ganglion blocking; histamine release.
63	iodide; Dimethine; Metubine)	Mouse	0.08-0.1	0.16		
64	$C_{40}H_{48}N_2O_6I_2 \cdot 3H_2O$	Rabbit	0.01-0.015	0.02	Neostigmine.	
65		Rat	0.009	0.025-0.03	Neostigmine.	Histamine release.
66		Frog[2]	0.74	14.4		

/1/ Unless otherwise indicated, drug administered by intravenous injection. /2/ Ventral lymph sac injection. /3/ Subcutaneous injection.
/4/ Oral administration.

Data presented in this table are substantiated by experimental and clinical evidence. Except in a few instances, and so indicated, unauthenticated

	Characteristic	Gaseous Agents: Nitrous Oxide	Ethylene	Cyclopropane
	Physical and Chemical Characteristics			
1	Chemical formula	N_2O	$H_2C{=}CH_2$	
2	Molecular weight	44.02	28.05	42.08
3	Color, odor, taste	Colorless, odorless, tasteless or sweet.	Colorless, slightly sweet.	Colorless, odor like petroleum benzene, pungent.
4	Specific gravity[4]	1.53	0.97	1.45
5	Boiling point, °C	-89	-103.9	-37
6	Range of flammability in[5]: Air	Not flammable, but supports combustion.	3.05-28.6%.	2.45-10.45%.
7	Oxygen		3.10-79.9%.	2.48-60.00%.
8	Stability to alkali[6]	Stable.	Stable.	Stable.
9	Oil / Blood Ratio[7]	0.437 / 0.412=1.06	1.599 / 0.123=13	6.99 / 0.457=15.3
10	Potency[8], %	25	30	100
11	Methods of administration[9]	Semi-closed, closed.	Semi-closed, closed.	Closed.
12	Induction time[10], average	Less than 5 min without hypoxia.	2-3 min without hypoxia.	2-5 min.
13	Recovery time[11], average	Rapid, 2-3 min.	Rapid, 2 min.	Immediate to 15 min.
	Concentration in inspired air for[12]:			
14	Analgesia, %	20-40	25-35	4-6
15	Surgery, %	85-90	80-85	13-25
16	Respiratory arrest, %	Not without anoxia.	Not without anoxia.	40
	Blood concentration for[12]:			
17	Surgery	23.3 vol %.	11.2-12.6 vol %.	4.5-9.1 vol %; 16-20 mg %.
18	Respiratory arrest	Not without anoxia.	Not without anoxia.	39 vol %; 30 mg %.
19	Routes of elimination[13]	Lungs, small quantity through skin.	Lungs, small quantity through skin.	Lungs, small quantity through skin.
	Physiological Effects[14]			
20	Respiratory center	Not affected.[15]	Not affected.	Decreased response to carbon dioxide; decreased minute volume.
21	Carotid body	Not affected.[15]	Not affected.[15]	Not affected.[15]
22	Larynx	Reflex not abolished; no spasm without hypoxia.	Reflex not abolished; no spasm without hypoxia.	Frequent laryngospasm.
23	Cilia	None without hypoxia.	Initial stimulation.	
24	Bronchi	Minimal bronchoconstriction or not affected.	Not affected.	Tends to produce bronchoconstriction.
25	Carotid sinus	Increased sensitivity or not affected.	Little effect.	Little effect.
26	Heart	None without hypoxia.	None without hypoxia.	Bradycardia, A-V nodal rhythm, ventricular extrasystoles, ventricular tachycardia, ventricular fibrillation, reduction in cardiac reserve.

/1/ Marketed as Vinethene which has added to it 3.5% alcohol to decrease its rate of vaporization, and 0.01% phenyl-a-naphthylamine as a preservative; be an improvement over diethyl ether. /3/ Stabilized with 0.01% thymol and tinted (for anesthetic use) to distinguish it from chloroform which has /5/ Range of inflammability for all inflammable agents lies within the anesthetic range. Non-inflammable agents either support combustion or prodroxide and calcium hydroxide, is used to absorb CO_2 in all closed systems. /7/ A loose term, sometimes refers to water or blood, or to vegetion is a partial function of the oil/blood ratio. /8/ A relative term indicating the ability of an anesthetic agent to take a patient from consciousness ularly the central nervous system. There is a progressive brain depression from cortex to lower centers, followed by an ascending paralysis of the administration of a volatile anesthetic by dropping the agent on a gauze-covered wire-mesh face mask. "Semi-open" is the same technique, with the rebreathes the same mixture of gas with suitable means for the absorption of carbon dioxide and the introduction of a continuous supply of oxygen and tion" is the blowing of the anesthetic vapor and oxygen into the pharynx or trachea in sufficient quantity and rate to maintain anesthesia. /10/ Averdividual metabolism, rate and depth of ventilation, cardiovascular system, effect of previously administered drugs, addiction to barbiturates or ation and average depth of anesthesia--particularly the depth at termination of surgery--effective ventilation, status of the cardiovascular system, oxide. /12/ Concentrations to produce a given plane of anesthesia vary considerably from individual to individual. Each patient must be carefully end products, probably related to the metabolism of chloroform and trichlorethylene, have been discovered in the urine. /14/ Those listed presupautonomic blocking agents, sympathicommetic agents, endocrines, and muscle relaxants, significantly modify these effects. /15/ No data avail- among anesthesiologists.

impressions and opinions have not been included. Blank spaces indicate unavailability of data.

Volatile Agents						
Diethyl Ether	Divinyl Oxide[1]	n-Propyl Methyl Ether[2]	Chloroform	Trichlorethylene[3]	Ethyl Chloride	
Physical and Chemical Characteristics						
C_2H_5-O-C_2H_5	CH_2=CH-O-CH=CH_2	C_3H_7-O-CH_3	$CHCl_3$	HClC=CCl_2	CH_3CH_2Cl	1
74.12	70.09	74.08	119.39	131.40	64.52	2
Colorless, pungent, irritatng, sweetish, burning.	Colorless, odor like garlic.	Colorless, ethereal, unpleasant, non-irritating.	Colorless, ethereal, burning, sweet.	Colorless, similar to chloroform.	Colorless, ethereal, burning.	3
0.713-0.716	0.767-0.771	0.726	1.474-1.478	1.456-1.462	0.921	4
2.56	2.2		4.12	4.53	2.23	
35	28-31	39	61	86-88	12-13	5
1.85-25.9% 2.1-82.0%	1.70-27.0% 1.8-85.0%	Same as diethyl ether.	Not flammable, but produces phosgene near naked flames.	Not flammable in air, but products of decomposition explosive. 10.3-64.5%	4.0-14.8% 4.05-67.2%	6 7
Stable.	Stable.		Little decomposition under anesthetic conditions; some carbon monoxide produced.	Decomposes, producing dichloracetylene and phosgene.	Hydrolysed slowly by alkali.	8
4.1	41.3	10±1	147.5-275.0 —>99.1-103.5 1.42-2.77	34.4	15.3	9
100	100	100	100	25-30	100	10
Open; semi-open; closed; semi-closed; insufflation, rectally.	Open; semi-open; closed; semi-closed.	Open; semi-open; closed; semi-closed; insufflation.	Open; semi-open; closed(?); semi-closed; insufflation.	Semi-closed, rectally.	Open; semi-open; closed.	11
10-15 min.	15 sec-5 min; average one min.	5 min.	9 min.	Difficult induction 5-10 min.	15 sec-5 min; average one min.	12
½-2 hr.	Rapid, almost immediate on discontinuing agent.	Prolonged up to 3 hr.	½-1 hr.	2-5 min.	Rapid, almost immediate.	13
6.1-13.7 vol %.	Almost impossible to produce. 3.9 10-12		0.67	0.5 5.0-7.5	2-3 3.6-4.5 6	14 15 16
120 mg %. 154 mg %.	11-18 mg %. 68 mg %.	40-70 mg %.	9.2 mg %. >16.5 mg %.		20-30 mg %. 40 mg %.	17 18
67% by lungs; remainder in urine, perspiration and by exposed serous surfaces.	Lungs, small amount in urine.	Probably same as diethyl ether.	98% by lungs; some in urine possibly as trichloromethyl-glucoronate.	Lungs, urine.	Exclusively through lungs.	19
Physiological Effects[14]						
Decreased response to carbon dioxide; increased minute volume.	Stimulated in minimal dosage.	Irregular, fairly quiet respirations.	Depressed.	Tachypnea and shallow irregular breathing in deep planes; sudden respiratory arrest.	Depressed.	20
Markedly depressed.			Remains active[15].			21
Laryngospasm caused by direct irritant effect.	Laryngospasm infrequently.		Laryngospasm caused by high concentrations.	Minimal tendency to laryngospasm.	Infrequent laryngospasm.	22
Possibly initial stimulation, later decrease in activity.			Decreased activity.			23
Bronchodilatation.	Bronchodilatation.		Bronchodilatation.			24
Markedly depressed in deep planes.	Stimulated in light planes; depressed in deep planes.		Stimulated to 1%; but depressed by higher concentrations.			25
Auricular extrasystoles, A-V nodal tachycardia; in deep planes dilatation and decreased force of contraction.	A-V nodal tachycardia or no notable cardiac effect.	No change in electrocardiogram.	Ventricular extrasystoles, nodal and ventricular rhythms, ventricular tachycardia; incidence increased by adrenalin, overdosage, and anoxemia.	Nodal rhythm, ventricular extrasystoles, pulsus bigeminus.	Increase in cardiac irritability during induction; myocardial depression, slight decrease in cardiac output.	26

ative. /2/ Included here as an example of a recent product developed in the search for an ideal anesthetic agent, although it has not proved itself to a similar odor. /4/ Water and air are the reference points and in each case equal unity. Upper figures of the volatile agents are the liquid phase. duce toxic products in the presence of a flame. /6/ A mixture of sodium hydroxide and calcium hydroxide, or of barium hytable oils or brain lipids. The significance herein is that the rapidity of induction is a partial function of the air/blood ratio, and the rate of desaturato death without hypoxia, according to the accepted stages and planes (see Table 330). Anesthetic agents produce a depression of all tissues, particspinal cord. The respiratory and cardiovascular centers function until death is produced by an agent of 100% potency. /9/ "Open" means addition of an occlusive material wrapped about the face mask to increase the concentration of the vapor. "Closed" is the method in which the patient anesthetic agent. "Semi-closed" is the same technique except that expiration partly escapes into the atmosphere via an exhalation valve. "Insufflage induction time depends on several factors including the following: chemical or physiological properties and concentration of the anesthetic, innarcotics, and experience of the anesthetist. /11/ Average recovery time is related to many factors including, fat solubility of the anesthetic, duraccidents during the anesthesia (such as the aspiration of pus, blood, or vomitus), bouts of severe hypoxia, and persistent accumulation of carbon dioequilibrated with the anesthetic. /13/ It is assumed that many anesthetic agents are excreted, principally by way of the lungs, unchanged. However, pose administration of a single agent with adequate oxygen and without accumulation of carbon dioxide. Other drugs, such as metabolic depressants, able in the literature or available data sketchy and based on clinical impression or animal experiments. Statements are from consensus of opinion

Data presented in this table are substantiated by experimental and clinical evidence. Except in a few instances, and so indicated, unauthenticated

	Characteristic	Gaseous Agents		
		Nitrous Oxide	Ethylene	Cyclopropane
		Physiological Effects[14] (concluded)		
27	Eyeball activity	Present, becomes fixed in prolonged anesthesia.	Present at all times.	Fixed in 2nd to 3rd plane.
28	Pupillary size[16]	Dilated, becomes constricted in prolonged anesthesia.	No effect.	Constricted, becomes dilated in 3rd plane
29	Salivary glands	None without hypoxia.	None without hypoxia.	90% increase in secretion during induction.
30	Liver	Retention of bromsulfthalein for few post-operative days.	None without hypoxia.	Bromsulfthalein may be retained from 15-30% post-operatively, bile secretion increased.
31	Kidney	None without hypoxia.	None without hypoxia.	31% decrease glomerular filtration, 52% decrease renal plasma flow, 35% increase filtration fraction; slight decrease urine flow; increased tubular reabsorption.
32	Spleen	Not affected.[15]	Not affected.[15]	Dilated.[15]
33	Adrenals	No secretion without hypoxia.	No secretion without hypoxia.[15]	Some secretion of adrenalin (cats).
34	Stomach and intestines	Slight increase in peristalsis followed by decreased tone in recovery period.	Decreased gastric secretion and gastric emptying time; little effect, in deeper planes inhibition of peristalsis.	Little effect; in deeper planes inhibition of peristalsis; some increase in tone; some spasm of colonic muscles.
35	Uterus	Contractions essentially unaltered.	Slight decrease in strength of contractions.	Decreased strength of contractions.
36	Skeletal muscles	Inadequate relaxation.	Moderate relaxation.	Adequate muscle relaxation obtainable.
37	Blood volume[17]	Increased because of increase in red cell mass.	No significant change.[15]	Increased because of increase in red cell mass.
38	Body temperature	Not affected.[15]	Slight fall caused by muscular relaxation.	Skin temperature tends to rise.
39	Peripheral blood vessels	Vasodilatation.	Vasodilatation.	Vasodilatation; in capillaries rapid restricted flow and increased vasomotion.
40	Autonomic effect	None.	Not sympatheticomimetic, not parasympatheticomimetic.	Parasympatheticomimetic, late adrenolytic effect(?).
41	Metabolic rate	Decreased.	Decreased.	Decreased.
42	Acid base balance	None without anoxia.	None without anoxia.	Respiratory acidosis occurs; clinically unimportant tendency for fixed acids to rise.
43	Special features	Should not be used in conjunction with hypoxia.	Absence of sweating.	Post-anesthetic hypotension and delirium; concurrent use of epinephrine may lead to ventricular tachycardia and fibrillation.

/1/ Marketed as Vinethene which has added to it 3.5% alcohol to decrease its rate of vaporization, and 0.01% phenyl-α-naphthylamine as a preservbe an improvement over diethyl ether. /3/ Stabilized with 0.01% thymol and tinted (for anesthetic use) to distinguish it from chloroform which has drugs, such as metabolic depressants, autonomic blocking agents, sympathicomimetic agents, endocrines, and muscle relaxants, significantly modify are from consensus of opinion among anesthesiologists. /16/ May be modified by a narcotic, a barbiturate, or a belladonna derivative used in preand blood during surgery. Maintenance of body temperatures during surgery is also a factor in fluid shifts from one body compartment to another.

impressions and opinions have not been included. Blank spaces indicate unavailability of data.

Volatile Agents						
Diethyl Ether	Divinyl Oxide[1]	n-Propyl Methyl Ether[2]	Chloroform	Trichlorethylene[3]	Ethyl Chloride	
Physiological Effects[4] (concluded)						
Present plane 1; fixed plane 2.	Rhythmic activity in light stage III.	Eyeballs may remain eccentric in plane 4.	Strabismus in light planes.	Nystagmus during induction and recovery.	Rotate into plane 3.	27
Dilated stage II, constricted plane 1; dilated plane 3.	Pupillary reflex to light remains active.	Pupils may remain constricted in plane 4.	Dilated in stage II.	Usually constricted in surgical plane.	Dilated in light planes.	28
350% increase in secretion during induction, depressed in surgical plane.	Profuse salivation.	Increased secretion in some patients.	500% increase in secretion during induction.	Not stimulated.	Little secretion.	29
Bromsulfthalein may be retained from 15-30% post-operatively; bile secretion decreased.	No impairment in obstetrics after one hr of anesthesia; no impairment bile secretion; possible liver damage in humans; liver necrosis in dogs.	No histologic damage in dog, rat, and monkey.	Greater retention of bromsulfthalein and higher cephalin flocculation post-operatively than with other agents. Can be markedly damaging, and acute yellow atrophy may occur especially with hypoxia.	Clinically non-toxic; no histologic changes noted.	Jaundice and fatty degeneration noted after repeated administration.	30
21% decrease glomerular filtration, 39% decrease renal plasma flow, 25% increase filtration fraction, 51% decrease urine flow, increased tubular reabsorption.	Oliguria or anuria, with decreased urea clearances in dogs.	No histologic damage in dog, rat, and monkey.	Decrease in urea clearance and changes in other tests similar to those obtained with other agents.	No histologic changes noted.		31
Constricted			Constricted			32
Adrenalin secretion stimulated.	No stimulation of adrenalin secretion.		Effect undecided.			33
Decreased peristalsis, decreased tone, decreased colonic contractions.	Increased tone and decreased peristalsis of stomach, decreased tone and peristalsis of intestines, decreased colonic contractions.		Decreased peristalsis, decreased colonic contractions.		Spasm of colonic muscles.	34
Decreased contractions.	Contractions not decreased.		Marked decrease in strength of contractions.	Little effect.		35
Adequate relaxation; sensitizes myoneural junction to curare.	Adequate relaxation in proper plane.	Excellent relaxation in 2nd plane.	Excellent relaxation.	Usually inadequate relaxation.	Usually inadequate relaxation.	36
Increased with some decrease of plasma volume and increase of red cell mass.			Decreased.[15]			37
Usually decreased but patient poikilothermic.			Decreased.	Decreased.		38
Vasodilatation; in capillaries rapid unrestricted flow and decreased vasomotion.			Vasodilatation.	Constriction of vessels, relatively less capillary bleeding.	Vasodilatation.	39
Sympathicomimetic.	Sympathicomimetic[15] in some respects.		Sympathicomimetic.	May increase vagal tone.		40
Decreased.			Decreased.			41
Tendency for metabolic acidosis to occur.	Minimal disturbance of acid-base balance.		May result in metabolic acidosis.			42
Convulsions occasionally occur during narcosis probably associated with hypoxia or hypercardia.	Convulsions during induction, maintenance, or recovery in unpremedicated patients. Running movements in dogs.	Overdose produces marked depression of blood pressure.	Sudden death from ventricular fibrillation or arrest may occur during induction.	Convulsions may occur in children under 2 yr, specific anesthesia of 5th cranial nerve.	Ventricular fibrillation may occur during induction.	43

ative. /12/ Included here as an example of a recent product developed in the search for an ideal anesthetic agent, although it has not proved itself to a similar odor. /14/ Those listed presuppose administration of a single agent with adequate oxygen and without accumulation of carbon dioxide. Other these effects. /15/ No data available in the literature, or available data sketchy and based on clinical impression or animal experiments. Statements medication. /17/ These studies were done primarily on animals before literature appeared concerning adequate replacement of fluid, electrolytes,

The use of certain trade names is for informative purposes only and in no way is intended to imply

Part 1: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects indicated in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = veasels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O_2 = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. = - = decreases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is pre-

	Drug	MABP	Car. O.	TSVR	Cer. BF	Cer. VR	Cer. O_2	LBF	LELV	RBF
1	Acetazoleamide									
2	Acetylcholine									
3	Aconitine									
4	Alkavervir				-12	-28	+17			
5	Aloeroxylon									
6	Ambonestyl									
7	Aminophylline	+7 to +8	+6 to +33	-4 to -19	-25 to -33	+8 to +24	0 to -18			
8	Ammonium chloride			+26 to +44	-21	+23	+5			+12 to +30
9	Amobarbital sodium	-8 to -13	-26							
10	Amphetamine sulfate									
11	Amyl nitrite				-2	+4	+4			
12	Atropine sulfate							+	Dilates	
13	Azamethonium bromide	-8	+23		-8 to +12	-20 to -35	+7 to +10	+	0	0 to -8
14	Aspetine phosphate							+		-7
15	Barium chloride							+		
16	Benzathine penicillin G									
17	Bishydroxycoumarin									
18	Caffeine and sodium benzoate				-13	+22 to +28	+8 to +9			
19	Calcium chloride									
20	Carbachol	-7	+12	-17						
21	Chloralose									
22	Chlorisondamine dimethochloride									
23	Chloroform							+		-
24	Chloroquine diphosphate									
25	Chlorpromazine				-9	-24	+4			
26	Cocaine									
27	Corticotropin				0	0	-14			
28	Cortisone acetate	+	0							
29	Cyanocobalamin				-56	+177	+22			
30	Cyclopentamine									
31	Cyclopropane	0	0	0						
32	Deslanoside									
33	Deoxycorticosterone acetate				-5	+6	-10			
34	Dextran									
35	Dextroamphetamine sulfate									
36	Dibenamine hydrochloride	-6 to -9	-6 to +28	-4						
37	Digifolin									
38	Digilanid									
39	Digitalis	-5 to +	-2 to +46	-32 to +3	-4	-9	+13			
40	Digitoxin									
41	Digoxin	0 to +8	-15 to +29	-28 to +7						
42	Dihydroergocornine methanesulfonate				0 to -8	-12 to -31	-8 to +3	+	Constr.	+12 to +19
43	Dihydroergotamine methanesulfonate	+3	0	+45						
44	β-Dihydrosolasodine									
45	Diphenhydramine hydrochloride									
46	Diphenylhydantoin sodium									
47	1, 1-Dimethyl-4-phenyl-piperazinium I									
48	Dioxyline phosphate									
49	Ephedrine sulfate	+10	+27	-13						
50	Epinephrine bitartrate	+ or -	+33 to +52	-35	-4 to +22	0	-3 to +28	+	Dil/constr.	-10 to -55
51	Erythrityl tetranitrate									
52	Ether	-5	+71 to +100	-44						
53	Ethyl alcohol	0	-5		-18 to +18	-35 to +12	-10 to +16	+	Dilates	
54	Ethyl chloride									
55	ε-Fagarine									
56	Gelatin, 6% solution									
57	Gitalin									
58	Glyceryl trinitrate	0	+		-8	-4	-3			
59	Heparin				-3	0	+4			
60	Hexamethonium bromide or chloride	-20 to -35	-46 to +38	-12 to -60	-4 to -42	-11 to -45	-12 to +4	0 or +	0	-59 to +17
61	Histamine diphosphate				0	-30	+6		Dilates	+28
62	Hydergine	-4	0	-5				+	Constr.	-11 to +5
63	Hydralazine	-10 to -41	+27 to +110	-31 to -61				0 or +	Dilates	-30 to +38
64	Hydroxyamphetamine hydrobromide	+30	0	+						
65	Inositol hexanitrate									
66	Insulin			+11 to +16	-6 to -13	-21 to -42				
67	Isoproterenol hydrochloride	+ to -	+26				+	dilates		
68	Khellin	+5	0/-6							
69	Lanatoside c	+	+							
70	Levarterenol bitartrate	+15 to +30	-6 to +32	+12 to +31	-8 to -21	-8 to +53	-5 to -15	0	Constr.	-47 to +181
71	Lobeline									
72	Magnesium sulfate									-10
73	Mannitol hexanitrate									
74	Mecamylamine hydrochloride									-21
75	Meperidine									
76	Mephentermine sulfate	+	0	+						

/1/ Caffeine citrate.

CARDIOVASCULAR SYSTEM

endorsement by the National Academy of Sciences-National Research Council for use of the drug.

AND CARDIAC EFFECTS

ing hyper-, hypo-, and normotensive persons. Where quantitative data are not available, direction of action is indicated as follows: + = increases; sented in Parts II, III, and IV of this table where the drugs are identified by their number in Part I. The following abbreviations have been employed cerebral blood pressure; Cer. VR = cerebral vascular resistance; Cer. O_2 = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on pulmonary arterial blood pressure; Pul. BF = pulmonary blood flow; Pul. VR = pulmonary vascular resistance; LEPV = local effects on pulmonary cardiac excitability; Car. RP = cardiac refractory period; Car. CT = cardiac conduction time; Car. Con. = cardiac contractility.

RVR	Hep. BF	Hep. VR	PABP	Pul. BF	Pul. VR	LEPV	Cor. BF.	Cor. VR	Car. O_2	Car. R	Car. Ex.	Car. RP	Car. CT	Car. Con.	
			+ or 0			Constr.	+128	-59		+ or -	+	-	+ or -		2
											+				3
															4
															5
			+ to -25	+6 to +33	-37 to +4	Dilates	+1 to +76	-		+	-	+		+	6
															7
															8
															9
										+				+	10
			0			+ to -	+20	-		+	-	+	+ or -		11
-12 to -23															12
															13
															14
											+			+	15
															16
															17
										+[1]				+[1]	18
											+		+	+	19
															20
															21
0	-	+													22
											+			-	23
											-		+		24
											-				25
															26
															27
															28
															29
															30
											+			-	31
															32
															33
			+50	+36											34
															35
			-21 to -27	-6 to +7	-17 to -34	?					-				36
															37
															38
			-40	+46	-					-	+ or -	+ or -	+	+	39
															40
			-12 to +7	0 to +29		0									41
															42
															43
			+28 to +38	0	+41 to +45	0					-				
											-				44
											-	+			45
											-				46
															47
															48
+270	+107		+20	+30	+ or -	Constr.	+35	-		+				+ or -	49
										+ or -	+ or -	-	+ or -	+	50
															51
											-			-	52
	+45						+60 to +117	-46 to -57	+1						53
															54
											-	+	+		55
															56
															57
							+10 to +80	-							58
											-			+	59
-55 to +14	-28 to -33	+5	-14 to -35	0 to -16	-35 to +21	0		-14 to -15	- to +3	+2					60
-			+			Constr.	+128	-59							61
-8			0	0	0	0									62
	+34 to +58	-41 to -56	-9 to +45	+25 to +110	-60 to +27		+34	-35	-5						63
			+												64
															65
															66
			-			Dilates									67
			0 to -4	0 to -6	0	0	+	-		+	0				68
			+ or -	+	-	0									69
-7 to +270	O to -32	O to +	+33	-6	0	Constr.				+ or -	+				70
															71
											-				72
															73
0															74
											-				75
			+	0	+									+	76

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Part I: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects including decreases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is presented in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = vessels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O_2 = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. =

	Drug	MABP	Car. O	TSVR	Cer. BF	Cer. VR	Cer. O_2	LBF	LELV	RBF
77	Merraluride sodium									
78	Mercurophylline sodium									
79	Mersalyl sodium		+19							
80	Metaraminol bitartrate	+50	0	+55	-9	+50	-6			-4
81	Methacholine chloride	-7	+29					0	Dilates	
82	Methamphetamine hydrochloride									
83	Methantheline bromide									
84	Methoxamine hydrochloride	+	-30	+						
85	Methoxyphenamine hydrochloride									
86	Methylhexeneamine									
87	Morphine									
88	Naphazoline hydrochloride									
89	Nicotine									
90	Nicotinic acid	1(?)	-4		+6	+9	-3	-	Dilates	
91	Nikethamide									
92	Nitrous oxide									
93	Norefrine									
94	Oenanthyl hydrochloride									
95	Ouabain									
96	Papaverine hydrochloride				+8 to +12	-17 to -22	0 to +4			
97	Parephyllin				-4	+3	+23			-13 to -18
98	Pentaerythritol tetranitrate									
99	Pentamethonium chloride	-11	+29					+	0	
100	Pentobarbital sodium							+	Dilates	
101	Pentolinium tartrate									
102	Phenobarbital sodium									
103	Phenoxybenzamine hydrochloride				-12	-31	-14	+		+15 to +57
104	Phentolamine HCl or methanesulfonate				0	-21	0	+	Dilates	
105	Phenylephrine hydrochloride	+35	-28	+						
106	Phenylpropanolamine hydrochloride									
107	Phenylpropylmethylamine									
108	Piperoxan hydrochloride									
109	Pituitary extract (posterior)	-2	-2 to -54	-1						
110	Potassium chloride									
111	Potassium thiocyanate									
112	Procaine hydrochloride	- to +2	-2 to +23		-2 to -12	-16 to +8	-3 to -6	+ or -	Dilates	
113	Procaine amide hydrochloride	-17	-11	+5						
114	Procaine penicillin G				+18	-11	+10			
115	Propylhexedrine									
116	Protoveratrines A and B maleate							0	0	-7 to -25
117	Pyrilamine maleate									
118	Quinacrine hydrochloride									
119	Quinidine gluconate									
120	Quinidine hydrochloride									
121	Quinudine sulfate	0 to -25	0 to -4	- to +4						
122	Rauwolfia									
123	Rescinnamine									
124	Reserpine	0 or -	+ or -		+2	-17	-3			0
125	Ronicol tartrate							0		
126	Scillaren A									
127	Scillaren B									
128	Scopolamine hydrobromide									
129	Serotonin	+	+30	-3						
130	Sodium bicarbonate				+30 to +69	-25 to -39	-6 to +8			
131	Sodium chloride				0 to +12	-6 to -7	0 to -8			+4
132	Sodium cyanide									
133	Sodium lactate									
134	Sodium nitrite	-3 to -5	+10 to +21	-13 to -15						
135	Sodium salicylate	+3	+14							
136	Sodium sulfide									
137	Sodium thiocyanate	0	-18	+						
138	Strophanthin									
139	Succinylcholine chloride									
140	Synephrine									
141	Tetraethylammonium chloride or Br	-5 to -21	-32 to +35	-27 to -28				+	+ or -	
142	Thiamine hydrochloride									
143	Thiopental sodium	-4 to -19	-20 to -25	0 to +4	-25 to +11	-19	0 to -39			
144	Thiouracil				-13	+31	-14			
145	Tolazoline hydrochloride	+8	+28		-12 to +22	-25 to +6	-3	+	Dilates	
146	Trichlorethylene									
147	Triethanolamine trinitrate $BiPO_4$									
148	Trimetaphen camphorsulfonate	-5 to -38	-18 to -19	-8 to -22						0 to -18
149	Trimethadione									
150	Tripelennamine hydrochloride									
151	Tuaminoheptane sulfate									
152	Tubocurarine chloride								Dilates	
153	Urethane									

ing hyper-, hypo-, and normotensive persons. Where quantitative data are not available, direction of action is indicated as follows: + = increases; sented in Parts II, III, and IV of this table where the drugs are identified by their number in Part I. The following abbreviations have been employed cerebral blood pressure; Cer. VR = cerebral vascular resistance; Cer. O_2 = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on pulmonary arterial blood pressure; Pul. BF = pulmonary blood flow; Pul. VR = pulmonary vascular resistance; LEPV = local effects on pulmonary cardiac excitability; Car. RP = cardiac refractory period; Car. CT = cardiac conduction time; Car. Con. = cardiac contractility.

RVR	Hep. BF	Hep. VR	PABP	Pul. BF	Pul. VR	LEPV	Cor. BF.	Cor. VR	Car. O_2	Car. R	Car. Ex.	Car. RP	Car. CT	Car. Con.
+56			+93	0	+									
										+ or -	+	-	+ or -	
											-			+
			-	-	-	0	-10 to +	+			0			-
	-6	-17												
							+3 to +45	-	+13					-
							-11	+34	+4					
			+			+1 or -	+20 to +60	-			-	+	+	
											-			-
-31 to -50														
											-			
			+70	-	+						0			0
														+
														+
			+	-54	+	+ or -								
											+ or 0		+	
	-24 to -33	+1 to +7	-17 to -34	-16 to -31			-52	+7	-53	+	-			
			-	-11		0				+	-	+ or 0	+	-
+ or -														
											-			
										+	-	+	+ or -	-
											-			-
			+	+/-	+50	constr.								
			+66	+19										
			-10 to -18	+10 to +11	-19 to -20	+ or 0								
							-1 to +9	-3 to -5	-5 to +24					
			-3 to -29	-32 to +12	+ to -35	0				+	+			
											0			-
											-			
											+			
-36 to +33														
											+			+
														-

The use of certain trade names is for informative purposes only and in no way is intended to imply

Part I: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects including: + = increases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is present in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = vessels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O_2 = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. =

	Drug	MABP	Car. O	TSVR	Cer. BF	Cer. VR	Cer. O_2	LBF	LELV	RBF
154	Urginin									
155	Veratramine									
156	Veratridine									
157	Veratrone	-11 to -14	0	-6 to -21				-	0	-
158	Vergitryl									
159	Vertavis									
160	Vinyl ether									

Part II: SITES OF ACTION

Numbers in brackets refer to drugs listed in Part I.

	Site of Action	Stimulant Drugs	Depressant Drugs
	NERVOUS MECHANISMS CONTROLLING CIRCULATION		
	Central Nervous System (Direct Action)		
1	Vasoconstrictor center	Analeptics [18, 91].	General anesthetics [23, 31, 52, 54, 92, 143, 146, 160].
2	Cardioaccelerator center		
3	Cardioinhibitory center[2]	General anesthetics [23, 31, 52, 54, 92, 143, 146, 160].	Analeptics [18, 91].
4	Other areas, unidentified	None recognized.	Rauwolfia alkaloids [5, 122, 123, 124]; hydralazine [63]; morphine [87].
	Sensory Receptors in Heart, Lungs, and Blood Vessels		
5	Stretch receptors in carotid sinuses and aortic arch[3]	Activated indirectly, and by local application of sympathomimetics [10, 30, 35, 49, 50, 64, 70, 76, 80, 82, 84, 86, 88, 93, 94, 102, 105, 106, 115, 140, 151]; veratrum alkaloids [4, 116, 157, 158, 159].	Local anesthetics [112]; receptors inactivated indirectly by hypotensive drugs [2, 7, 11, 20, 48, 51, 53, 58, 65, 68, 73, 81, 96, 97, 98, 134, 147].
6	Chemoreceptors in carotid and aortic bodies[4]	Ganglion stimulants [89]; oxidation inhibitors (e.g., cyanide, sulfide) [132]; papaverine [96]; nikethamide [91]; aminophylline [7].	Local application of ganglionic blocking agents [13, 22, 60, 74, 99, 101, 141, 148] depresses action of ganglion stimulants; oxygen inhalation depresses action of cyanide.
7	Stretch receptors in heart, lung parenchyma, blood vessels[5]	Veratrum alkaloids [4, 116, 157, 158, 159].	Local anesthetics [112].
8	Various receptors in respiratory passages and joints[6]	Veratrum alkaloids [4, 116, 157, 158, 159]; low concentration of volatile anesthetics [23, 52, 160].	High concentration of volatile anesthetics [23, 52, 160].

	Site of Action	Stimulant Drugs	Depressant Drugs
	NERVOUS MECHANISMS CONTROLLING CIRCULATION (Concluded)		
	Autonomic Nervous System		
9	Sympathetic[7] and parasympathetic[8] ganglia	Ganglion stimulants [89].	Ganglion-blocking agents [13, 22, 60, 74, 99, 101, 141, 148]; high concentration of nicotine [89].
10	Post-ganglionic nerve terminations: sympathetic[7]	Sympathomimetics [10, 30, 35, 49, 50, 64, 70, 76, 80, 82, 84, 86, 88, 93, 94, 102, 105, 106, 115, 140, 151].	Adrenergic blocking drugs [13, 22, 60, 74, 99, 101, 141, 148].
11	Post-ganglionic nerve terminations: parasympathetic[8]	Parasympathomimetics [2, 20, 81].	Parasympathetic blocking agents [12, 83, 128].
	MUSCULAR COMPONENTS OF CIRCULATORY SYSTEM		
	Smooth Muscle of Blood Vessels		
12	With specific antagonist	Methacholine [81].	Atropine [12].
13		Histamine [61].	Antihistamines [45, 117, 152].
14	Without specific antagonist	Musculotropic vasoconstrictors [109, 129].	Musculotropic vasodilators [7, 11, 48, 51, 53, 58, 65, 68, 73, 96, 97, 98, 134, 147].
	Heart		
15	Contractility of heart muscle	Digitalis glycosides [32, 37, 38, 39, 40, 41, 57, 69, 95, 126, 127, 138, 154].	Quinidine [121]; general anesthetics [23, 31, 52, 54, 92, 143, 146, 160].
16	Excitability of the heart	Profibrillatory drugs: chloroform [23]; cyclopropane [31].	Antifibrillatory drugs [6, 113, 119, 120, 121]; quinidine [121].

[1] None selective. [2] Reciprocal innervation with cardioaccelerator center. [3] Type 1 receptors producing perfect inhibition of vasoconstrictor, cardioaccelerator, and respiratory centers. [4] Type 3 receptors producing pure stimulation of vasoconstrictor, cardioaccelerator and respiratory centers. [5] Type 2 receptors producing imperfect inhibition of vasoconstrictor, cardioaccelerator and respiratory centers. [6] Type 4 receptors producing impure stimulation of vasoconstrictor, cardioaccelerator and respiratory centers. [7] Sympathetic stimulation causes cardiac acceleration and constriction of most blood vessels (peripheral). [8] Parasympathetic stimulation causes cardiac slowing and dilatation of most blood vessels.

CARDIOVASCULAR SYSTEM (Continued)

endorsement by the National Academy of Sciences-National Research Council for use of the drug.

AND CARDIAC EFFECTS (Concluded)

ing hyper-, hypo-, and normotensive persons. Where quantitative data are not available, direction of action is indicated as follows: + = increases; sented in Parts II, IIL, and IV of this table where the drugs are identified by their number in Part I. The following abbreviations have been employed cerebral blood pressure; Cer. VR = cerebral vascular resistance; Cer. O_2 = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on pulmonary arterial blood pressure; Pul. BP = pulmonary blood flow; Pul. VR = pulmonary vascular resistance; LEPV = local effects on pulmonary cardiac excitability; Car. RP = cardiac refractory period; Car. CT = cardiac conduction time; Car. Con. = cardiac contractility.

RVR	Hep. BF	Hep. VR	PABP	Pul. BF	Pul. VR	LEPV	Cor. BF.	Cor. VR	Car. O_2	Car. R	Car. Ex.	Car. RP	Car. CT	Car. Con.	
-	-	-	-10 to -29			0				-				-	154 155 156 157 158 159 160

Part III: "CARDIOVASCULAR DRUGS": USES AND EFFECTS

"Cardiovascular Drugs," for the purposes of this table, refers to those drugs used primarily in treatment of circulatory system disorders. Numbers in brackets refer to drugs listed in Part I.

	Drug Number, Synonyms, Trade Names	Route of Administration[1]	Effects: Desirable (D); Undesirable (U)
	ANTIHYPERTENSIVE DRUGS[2]		
	Veratrum Alkaloids		
1	[4], Veriload	PO, IM, IV	D: hypotension.
2	[176], Provell	PO	U: severe bradycardia, nausea, vomiting, salivation, sweating.
3	[1575, 1585, 1595]	PO	
	Rauwolfia Alkaloids		
4	[124][7], Serpasil, Serpiloid, Reserpoid, Raused, Serpate	PO	D: hypotension. U: mental depression, nasal congestion, nausea, bradycardia, weakness, fatigue.
5	[123][8]		
6	[122][9], Raudixin, Rauwsil		
7	[6][10], Rauwiloid, Rau-tension, Rau-Tab, Rauwistan		
	Miscellaneous		
8	[63], Apresoline	PO	U: nausea, constipation.
9	[111] (or sodium salt)		U: drowsiness, vomiting.
	VASODILATORS[11]		
	Ganglionic Blocking Drugs		
10	[(4)], Etamon	IV, IM	D: Incressed blood flow to limbs, lowering of arterial pressure if hypertensive. U: severe hypotension (unless intentional for hypertensive surgery; generalized ganglion blockade manifested by blurring of vision, dryness of mouth, tachycardia, constipation.
11	[60], Batrium, Methium, Estomid, Hexameton, Hiohax	PO, IV, SC	
12	[59]	IV	
13	[13], Pendiomide	IV	
14	[22], Ecolid	PO	
15	[74], Inversine		
16	[101], Ansolysen, Pentapyrrolidinium	PO	
17	[148], Arfonad	IV	
	Adrenergic Blocking Drugs		
18	[104], Regitine	PO, IV, IM	D: Increased blood flow to limbs; hypotensive action useful in diagnosis of pheochromocytoma. U: drowsiness, nausea, vomiting, tachycardia, nasal congestion.
19	[108], Benodaine	IV	
20	[43]	IV, IM	
21	[42]	IV, IM	
22	[62][12]	SL, IV, IM	
23	[14], Ilidar	PO, IV	
24	[25]	IV	
25	[103], Dibenzyline	IV, PO	
26	[125]	PO	
27	[145], Priscoline	PO, IV	
	Cholinergic Vasodilators		
28	[2]	IM, SC	U: peripheral vasodilatation accompanied by generalized parasympathomimetic actions.
29	[81], Mecholyl	SC	
30	[28], Doryl	SC	

	Drug Number, Synonyms, Trade Names	Route of Administration[1]	Effects: Desirable (D); Undesirable (U)
	VASODILATORS[11] (concluded)		
	Musculotropic Vasodilators		
31	[1]	IH	D: subjective relief of angina. U: syncope, methemoglobinemia, development of tolerance.
32	[58], Nitroglycerine	SL	
33	[134]	PO	
34	[73]	PO	
35	[98], Peritrate	PO	
36	[51]	PO	
37	[65]	PO	
38	[147], Metamine	PO	
39	[7], Theophylline ethylenediamine	PO, IM, IV	U: variable effects on coronary and limb blood flow; inconstant clinical results.
40	[97], Solophylline	IM	
41	[96]	IV, IM	
42	[48], Peveril	PO	
43	[68], Eskel	PO	
44	[53], grain alcohol	PO	
	HYPERTENSIVE DRUGS[13]		
	Sympathomimetic Amines: Systemic Pressure Action		
45	[50], Adrenaline, Suprarenin	SC, IV	D: Rise in systemic arterial pressure. U: some amines induce cardiac arrhythmias and cerebral excitation.
46	[70], Levophed, Noradrenaline	IV	
47	[49]	PO, SC, IM	
48	[64], Paredrine	IM, TOP	
49	[75], Wyamine	IM, IV, TOP	
50	[82], Methedrine, Desoxyephedrine, Desoxin, Doxoval, Droxyfed, Efroxine, Norodin	PO, SC, IM, IV, TOP	
51	[84], Vasoxyl	IM	
52	[105], Neosynephrine Isophrin	SC, IM, IV TOP	
53	[56], Clopane	IV, IM, TOP	
54	[94]	IV, IM	
55	[140], Sympatol, Synthenate	SC, IM	
	Sympathomimetic Amines: Local Application		
56	[10], Benzedrine, Actedrow	IH	D: local nasal decongestion. (With the exception of drugs [10] and [15], which fall in the same general category as [82], these amines are too toxic for parenteral use.)
57	[15], Dexedrine	TOP	
58	[68], Privine	TOP	
59	[15], Benzedrex	IH	
60	[151], Tuamine	IH, TOP	
61	[106], Propadrine	TOP	
62	[107], Vonedrine	IH, TOP	
63	[80], Aramine	TOP	
64	[66], Forthane	IH	
65	[93], Cobefrine	TOP	

/1/ PO = oral; IM = intermuscular; IV = intravenous; SC = subcutaneous; SL = sublingual; IH = inhalation; TOP = topical. /2/ For acute and chronic relief of essential and other forms of systemic hypertension. /3/ Mixture of alkaloids extracted from Veratrum viride. /4/ From Viscum album. /5/ Partially purified extract of Veratrum viride. /6/ Whole powdered preparation of V. viride. /7/ From Rauwolfia serpentina. /8/ Purified alkaloid. /9/ Powdered root of R. serpentina. /10/ Alkaloidal mixture from alseroxylon fraction of Rauwolfia extract. /11/ For improving blood flow in diseased limb and coronary vascular beds; for relief of systemic hypertension. /12/ Equal parts of dihydroergocornine-, dihydroergocristine-, and dehydroergokryptine methanesulfonates. /13/ Exert presser action for correction of hypotensive states; local vasoconstrictor action for nasal decongestion.

The use of certain trade names is for informative purposes only and in no way is intended to imply endorsement by the National Academy of Sciences-National Research Council for use of the drug.

Part III: "CARDIOVASCULAR DRUGS": USES AND EFFECTS (Concluded)

"Cardiovascular Drugs", for the purposes of this table, refers to those drugs used primarily in treatment of circulatory system disorders. Numbers in brackets refer to drugs listed in Part I.

	Drug Number, Synonyms, Trade Names	Route of Administration[1]	Effects: Desirable (D); Undesirable (U)
	CARDIOTONIC DRUGS[14]		
	Digitalis Purpureas Glycosides		
66	[37, 39, 40, 57]	PO	D: improve ventricular function of heart in failure with and without auricular fibrillation; A-V block. U: anorexia, vomiting, headache, ventricular arrhythmias; excessive A-V block.
67	[41]	PO, IV	
	Digitalis Lanata Glycosides		
68	[69], Cedilanid	PO	
69	[38]	PO, IV	
70	[32], Cedilanid D	IV	
	Strophanthus Gratus, S. Kombe Glycosides		
71	[95], Strophanthin G	IV	
72	[138]	IV	
73	[126, 154]	PO	Same as for Items 66-72.
74	[127]	IV	
	ANTIARRHYTHMIC DRUGS[15]		
	Cinchona Alkaloids		
75	[21]	PO	D: antifibrillatory action. U: cinchonism; vascular collapse following IV.
76	[119]	IM	
77	[120]	IM, IV	
	Synthetics		
78	[73], Pronestyl	PO, IV	U: Depression of cardiac muscle contractility; hypotension.
79	[6]	IV	

[1] PO = oral; IM = intermuscular; IV = intravenous; SC = subcutaneous; SL = sublingual; IH = inhalation; TOP = topical. [14] For management of congestive heart failure. [15] For prophylactic and curative control of cardiac arrhythmia.

Part IV: "NON-CARDIOVASCULAR DRUGS": USES AND EFFECTS

"Non-cardiovascular Drugs," for the purposes of this table, refers to those drugs used primarily in treatment of disorders other than those of the cardiovascular system. Numbers in brackets refer to drugs listed in Part I.

	Drug Number	Use in Clinical Disorder of Circulatory System	Nature of Cardiovascular Action
		Analeptics	
1	[61]	Stimulant to vasomotor and respiratory centers.	Direct effects (?) on heart and coronaries.
2	[18]		Direct stimulation of heart muscle and vasodilatation.
		Analgesics	
3	[125]	Antipyretic for rheumatic carditis.	Claimed to have direct effect on cardiac lesion.
4	[75, 87]	Sedative for acute myocardial infarction or acute congestive failure.	In large doses, vasomotor depression and bradycardia.
		Anesthetics, General	
5	[23, 31, 52, 54, 92, 143, 146, 160]	None directly. Cardiac patients may be subjected to general anesthetics if necessary.	Depressant to cardiac contraction. In general, all are vasodilators. [23, 31] can cause dangerous cardiac arrhythmias.
		Anesthetics, Local and Spinal	
6	[26, 112]	Applied locally to exposed heart to prevent arrhythmia during cardiac surgery.	Spinal anesthesia may reduce arterial blood pressure by sympathetic blockade and decreased thoracic movement.
		Antibiotics	
7	[16, 114]	Control of subacute bacterial endocarditis.	Secondary to arrest of infectious process.
		Anticoagulants	
8	[17, 59]	Prophylaxis against thromboembolic diseases.	Prevention of thromboses and emboli.
		Anticonvulsants	
9	[46, 149]	None	Antiarrhythmic activity.
		Antihistamines	
10	[45, 117, 150]	None.	Antifibrillatory action demonstrated in animals.
		Antimalarials	
11	[24, 118]	Antifibrillatory agent.	Decreased excitability of cardiac muscle.
		Anti-thyroids	
12	[44]	Treatment of hyperthyroid heart disease.	None directly.
		Diuretics	
13	[1, 77, 78, 79]	Mobilization of sodium ion and water in congestive heart failure.	Decreased blood volume aids in treating congestive heart failure. In large doses is depressant to cardiac muscle.
		Endocrine Preparations	
14	[27, 28, 33, 66]	None.	None.
15	[109]		Vasoconstrictor.

	Drug Number	Use in Clinical Disorder of Circulatory System	Nature of Cardiovascular Action
		Hypnotics and Sedatives	
16	[9, 100, 102]	Sedative in hypertension and heart disease.	In large doses, depressant to cardiac contraction.
		Ions	
17	[8, 15, 19, 72, 110, 130, 133]	Limited clinical trial as antiarrhythmus or as stimulants to arrested ventricles.	Alterations in excitability and automaticity of heart.
		Neuromuscular Blocking Agents	
18	[139, 152]	None.	Curare preparations cause hypotension through histamine liberation, ganglionic blockade, and decreased muscle tone.
		Parasympathetic Blocking Drugs	
19	[12, 83, 128]	Diagnosis and treatment of cardiac arrhythmia by virtue of increased vagal tone; antidote for antocholinesterase poisoning.	Cardioaccelerator.
		Plasma Extenders	
20	[34, 56, 131]	Plasma expander in shock.	Increased cardiac output.
		Sympathomimetic Bronchodilators	
21	[67, 85]	Relief of bronchial asthma.	Hypotension. Action unlike that of sympathomimetic amines [30, 49, 50, 64, 70, 76, 82, 84, 94, 105, 140].
		Tranquilizers	
22	[25]	Prevention of nausea in uremia, eclampsia, and veratrum therapy and relief of mental aberrations.	Essentially secondary to actions on nervous system.
		Vitamins	
23	[29]	None.	None.
24	[90]	Treatment of peripheral vascular disease.	Vasodilator(?).
25	[142]	Treatment of cardiac beri-beri.	None, unless deficiency symptoms exist.
		Miscellaneous[1]	
26	[3]	None because of toxicity.	Proarrhythmic.
27	[6]		Vasodilator.
28	[129]		Vasoconstrictor.
29	[47, 71, 89]		Ganglion stimulant.
30	[55]		Antiarrhythmic.
31	[44, 135]		Antiaccelerator.
32	[132, 136]		Chemoreceptor stimulant.
33	[156]		Visceral receptor stimulant.
34	[21, 153]		General anesthetic.

[1] For animal experimental use.

Part I: PHYSICAL AND CHEMICAL CHARACTERISTICS

↓ = decreased; ↑ = increased.

	Name, Synonyms, Chemical Formula (Systematic Name)	Properties[1]	Sources[1]	Assay Methods	Metabolites
	Adrenal Cortex				
1	Aldosterone; electrocortin; $C_{21}H_{28}O_6$ (Δ^4-pregen-18-al-11β, 21-diol-3,20-dione-11,18-hemiacetal)	MW=360; MP=164; $[\alpha]_D$ +160°(ch.); s. org. solv.; sl. s.w.	Adrenals (beef, hog, dog, monkey); human urine, placenta (?).	Urinary Na; K ratio in adre-x rats; recovery muscle fatigue (Everse and de Fremery test) in adre-x rats; muscular work performance (Ingle's test) in adre-x rats; deposition of liver glycogen (rats, mice); weight maintenance in adre-x dogs; survival and growth (Kuizenga test) in young adre-x rats; prevention of convulsions (anti-insulin test) in mice; protection against cold in adre-x rats; decrease in circulating eosinophils, circulating lymphocytes, thymus weight; chemical methods (formaldehydogenic, reducing properties, reaction with phenylhydrazine).	Unknown.
2	Desoxycorticosterone=DOC; acetate = DOCA or DCA; $C_{21}H_{30}O_3$ (Δ^4-pregnen-21-ol-3,20-dione)	MW=330; MP=141-142; $[\alpha]_D$ +178° (al.); s. acet., bz., chl., vol. solv., veg. oils; i.w.	Adrenal cortex; synth. commercially from cholesterol, diosgenin.		Pregnanediol; 17-ketosteroids; 17-OH-steroids(?).
3	Corticosterone; $C_{21}H_{30}O_4$ (Δ^4-pregnene-11β, 21-diol-3, 20-dione)	MW=346; MP=181-182; $[\alpha]_D$ +262° (al.); s. org. solv.; sl.s. veg. oils; v.s.s.w.	Adrenal cortex; urine; synth. from desoxycholic acid.		17-Ketosteroids (11-OH-androsterone and 11-ketoetiocholan-3-(α)-ol-17-one; Similar to those of corticosterone; 11-keto-pregnenediol main metabolite.
4	Dehydrocorticosterone; cortexone; $C_{21}H_{28}O_4$ (Δ^4-pregen-21-ol-3, 11, 20-trione)	MW=344; MP=178-180; $[\alpha]_D$ +258(al.); s. org. solv.; i.w.			
5	Hydrocortisone; 17-hydroxycorticosone; cortisol; $C_{21}H_{30}O_5$ (Δ^4-pregnene-11β-17α-21-triol-3, 20-dione)	MW=362; MP=217-220; $[\alpha]_D$ +161°0 (al.); s. chl., eth., veg. oils; sl. s.w.	Adrenal cortex; synth. from desoxycholic acid.		Similar to those of corticosterone (17-ketosteroids); cortisone (?).
6	Cortisone; 17-OH-11-dehydrocorticosterone; $C_{21}H_{28}O_5$ (Δ^4-pregnene-17α-21-diol-3,11,20-trione)	MW=360; MP=220-224; $[\alpha]_D$ +209° (al.); s. acet., chl., bz., eth., veg. oils; sl.s.w.			17-Ketosteroids, in small quantities.
7	Fluorocortisone; $C_{21}H_{29}O_5F$ (9-α-Fluoro-17β-[1-keto-2-hydroxyethyl] -Δ^4-androstene-3, 11-dione-17α-ol)	MW=380; MP=233-234(acetate); $[\alpha]_D^{25}$ +123° (acetate).	Synthetic.		
	Ovaries				
8	Equilenin; $C_{18}H_{18}O_2$ ($\Delta^{1,3,5;10,6,8}$-estrapentaen-3-ol-17-one)	MW=266; MP=258-259; $[\alpha]_D$ +289° (diox.); s. vol. solv.; sl.s. al., veg. oils; i.w.	Synth.; 4 stereoisomers; natural estrogen from pregnant mare urine.		One inactive stereoisomer is produced by catalytic dehydrogenator of estrone.
9	Equilin; $C_{18}H_{20}O_2$ ($\Delta^{1,3,5;10,7}$-estratetraen-3-ol-17-one)	MW=268; MP=238-240; $[\alpha]_D$ +308° (diox.); s. vol. solv.; sl. s. veg. oils; i.w.	Pregnant mare urine.	Colorimetric: phenolsulfonic acid (Kober); $ZnCl_2$/benzoyl Cl, sulfanilic acid/$NaNO_2$ (Pincus); spectrophotometric; estrus changes in vagina (immature rats, mice, Allen-Doisy).	Easily dehydrogenated to equilenin.
10	β-Estradiol; dihydro[-theelin, -folliculin, -estrone] ; di-OH-estrin; $C_{18}H_{24}O_2$ (3,17β-di-OH-1, 3, 5;10-estratriene)	MW=272; MP=178; $[\alpha]_D$ +82° (diox.); s. alk., vol. solv.; sl. s. veg. oils; i.w.	Urine (pregnant mare, rabbit, man); ovary (swine); testes (stallion); human placenta; synth. from cholesterol.		β-estradiol ⇄ estrone ⇄ α-estradiol
11	Estriol; theelol; tri-OH-estrin; $C_{18}H_{24}O_3$ ($\Delta^{1,3,5;10}$-estratriene-3, 16α, 17β-triol)	MW=288; MP=282; $[\alpha]_D$ +33-63° (diox.); s. vol. solv., alk.; sl. s. veg. oils; i.w.	Urine (pregnant ♀); placenta; synth. from estrone, β-estradiol.		estriol (principal metabolite in urine; excreted as water-soluble inactive glucuronide).
12	Estrone; theelin; folliculin; keto-OH-estrin; $C_{18}H_{22}O_2$ ($\Delta^{1,3,5;10}$-estratrien-3-ol-17-one)	MW=270; MP=255; $[\alpha]_D$ +172° (diox.); s. vol. solv., alk.; v. sl. s.w.; sl. s. veg. oils.	Adrenal cortex; urine (man, bull, steer); synth. from cholesterol, diosgenin.		
13	Progesterone; progestin; luteosterone; $C_{21}H_{30}O_2$ (Δ^4-pregnene-3, 20-dione)	MW=314; MP(α) ≈128, (β) ≈ 121; $[\alpha]_D$ ≈ +172-182° (diox.); s. vol. solv.; sl. s. veg. oils; i.w.	Corpus luteum, placenta, adrenal cortex; synth. from cholesterol or stigmasterol.		Pregnanediol.
14	Relaxin	Polypeptide(?); IEP=5.5; s. w. and 95% al.	Serum (pregnant ♀); placenta; corpus luteum.	Degree of relaxation of pelvic ligaments (guinea pig).	Unknown.
	Placenta				
15	Chorionic gonadotropin[2] (HCG; proian)	MW(HCG)=60,000-80,000; MW(PMS)=30,000(?); IEP(HCG)=3.2; IEP(PMS)=2.6; s.w., 50% acet., 60% al.; inactivated pH 2.0.	HCG-placenta, urine (pregnant woman; PMS-placenta; blood (pregnant mare).	Corpus luteum formation (mice); ovarian wt. (rat); ovulation (rabbit); repair ovarian cells (immature hypophysectomized rats).	HCG excretion; basis of Aschheim-Zondek pregnancy test.
	Testes (and Androgens from Urine)				
16	Testosterone; $C_{19}H_{28}O_2$ (Δ^4-androsten-17β-ol-3-one)	MW=288; MP=155-156; $[\alpha]_D$ +109° (al.); absorption maximum = 238 mμ; s. al., eth., vol. solv.; sl. s. veg. oils; i.w.	Testes (bull); synth. from cholesterol and dehydroandrosterone.	17-Ketosteroids (urine)[3]; alk.-m-dinitrobenzene; 3,5Cl$_2$-acetic anhydride (colorimetric); chromatography; capon comb growth; blackening of bill (sparrow); ♦wt, seminal vesicle, prostate (castrated rats).	Androsterone; etiocholanone.
17	Dehydroepiandrosterone; dehydroisoandrosterone; $C_{19}H_{28}O_2$ (Δ^5-androsten-3β-ol-17-one)	MW=288; MP(leaflets) 152-153; $[\alpha]_D$ +10.9° (al.); s. al., eth., bz.; precipitated by digitonin; i.w.	Urine (man, bull, pregnant cow); synth. from cholesterol.		Found only in urine in conjugated form.
18	Androsterone; $C_{19}H_{30}O_2$ (androstan-3-(α)-ol-17-one)	MW=290; MP=185.5; $[\alpha]_D$ +87.8° (diox.); s. vol. solv.; sl. s. veg. oils; not precipitated by digitonin; i. w.	Urine (man, bull, pregnant cow); synth. from cholesterol or sitosterol.		Found only in urine (probably a metabolite of testosterone).
19	Pregnenolone; $C_{21}H_{32}O_2$ (Δ^5-pregnen-3-(β)-ol-20-one)	MW=316; MP=193; $[\alpha]_D$ +28° (al.); s. chl., al., diox.; v. sl. s.w.	Testes (hog); synth. from stigmasterol, diosgenin and cholesterol.	None available.	Pregnanediol.

/1/ sc. = acid; acet. = acetone; al. = alcohol (ethanol, 95%); alk. = alkali; aq. = aqueous; bz. = benzene; chl. = chloroform; diox. = dioxane; eth. = ether; HCG = human chorionic gonadotropic; i. = insoluble; IEP = isoelectric point; me. al. = methyl alcohol; MP = melting point; MW = molecular weight; org. = organic; PMS = pregnant mare serum; pptd.= precipitated; s. = soluble; sl. = slightly; sol. = solution; solv. = solvents; synth. = synthesized; v. = very; vol. = volatile; w. = water; wt. = weight; -x = -ectomized (e.g., hypo-x = hypophysectomized). /2/ Placenta also produces estrogens and progesterone. /3/ Not applicable to testosterone.

Part I: PHYSICAL AND CHEMICAL CHARACTERISTICS (Concluded)

↓ = decreased; ↑ = increased.

	Name, Synonyms, Chemical Formula (Systematic Name)	Properties[1]	Source[1]	Assay Methods	Metabolites
			Anterior Pituitary		
20	Adrenocorticotropin; adrenotropin; adrenocorticotropic hormone; corticotropin; ACTH	MW=4500; IEP=4.7–4.8; $Sed_{20,w}$ 2.08; s. w.; 60-70% al.; basic polypeptide(s).	Anterior pituitary (especially sheep, ox, swine).	Adrenal repair, wt. maintenance (hypo-x rats); ↑ adrenal ascorbic acid (hypo-x rats); urinary excretion of corticoids (guinea pig).	
21	Follicle-stimulating hormone; thylakentrin; FSH	IEP=4.8; stable pH 7–8, 30 min at 75°; s. w., 50% acet., 70% al., 50% diox., ½ saturated $(NH_4)_2SO_4$.	Anterior pituitary (especially sheep, swine); urine (castrates); PMS.	Follicular growth (hypo-x rats); ↑ weight, ovary and uterus (hypo-x immature rats); ↑ uterine weight (immature mice).	FSH-like protein.
22	Growth hormone; somatotropin; GH	IEP=6.85; $Diff_{20}$=7.15x10^{-7}; visc. coeff.=7.64; s.salt sol.; sl.s.w.; HNO_3 and acetylation destroy.	Anterior pituitary (various species).	↑ tail length, tibial epiphyseal cartilage (hypo-x rats); body growth (hypo-x rats).	
23	Interstitial-cell-stimulating hormore; luteinizing hormone; ICSH; LH	Sheep: $Sed_{20,w}$=3.8x10^{-13}; IEP=4.6 Swine: $Sed_{20,w}$=6.8x10^{-13}; IEP=7.45 a.w.; 40% s.l., dilute salt solution.	Anterior pituitary (especially sheep, swine).	Repair interstitial cells; (hypo-x rats or mice); ↑ wt. ventral prostate (hypo-x rats); ↓ testes wt. (pigeon).	
24	Lactogenic hormone; luteotropin; galactin; prolactin; LTH	$Diff_{20}$=9x10^{-7}; IEP=5.5–5.73; visc. coeff.=6.65 $[\alpha]_D^{25°}$= -40.5°; s. acid, al., me, al.; sl.s. w., dil. salt sol.	Anterior pituitary (especially ox, sheep); urine, in small amounts.	↑ wt. crop sac, proliferation crop gland (pigeon); ↑ milk secretion (rabbit).	
25	Thyrotropic hormone[4]; thyrotropin; thyrotropic hormone; TSH	Inactivated by boiling, cysteine, ketene, trypsin, pepsin, chymotrypsin; non-diffusible.	Probably anterior pituitary (basophilic cells).	↑ I_2 thyroid (chicks); ↓ thyroid cell height (chicks); ↓ wt. thyroid gland (guinea pig).	
			Pituitary Intermediate Lobe		
26	Intermedin; "B"-hormone; middle lobe hormone; melanophore-expanding hormone	IEP=4.1; dialyzable; moderately heat stable; destroyed by trypsin; stable acid, alk.; s.w.; i. eth., acet.	Intermediate lobe (animals changing skin color); anterior lobe	Melanophore expansion (S. African clawed frog, birds, porpoise).	
			Posterior Pituitary		
27	Oxytocic hormone; oxytocin; pitocin; postlobin-G; posterior-lobe principle	IEP=7.7; not adsorbed on charcoal; destroyed by acid, trypsin, tyrosinase; s. w., concentrated acetic acid, me, al.	Posterior pituitary.	Contraction, isolated uterus (guinea pig); ↑ BP (chicken).	
28	Vasopressin; vasopressor principle; postlobin-V; vasopressor-antidiuretic principle; ADH; pitressin	IEP=10.8; adsorbed charcoal; (inactivated by trypsin, not pepsin; solubility as to oxytocin.		↑ BP (rat, dog); anti-diuretic activity (rats).	ADH-like material.
			Parathyroid		
29	Parathormone; PTH	IEP=5.6; inactivated by proteases, alk.; stable dilute acid; s.w., saline, eq.al., 94% acetic acid, conc. phenol; 50% glycerol; i. vol. org. solv.	Parathyroids.	Rate and degree of rise in serum Ca^{++} and decrease in serum phosphate (dogs).	
			Thyroid		
30	Thyroid hormone[5]; thyroxine; $C_{15}H_{11}O_4NI_4$; p-[(3,5-diiodo-4-OH-phenoxy)-3,5-diiodophenyl]-alanine	MW=777; needles; MP=232–233; $[\alpha]_D$ = 3.2° (NaOH); s.alk.w., alk. or acid sl.; i.w., al., vol. solv.	Thyroid gland; synth. from p-methoxyphenol and 3,4,5-triiodinitrobenzene.	↓ BMR, thyroid-deficient subject; limb bud growth, amphibian larvae; ↓ I_2 O_2 consumption.	Inactive iodinated compounds in bile; iodides.
			Pancreas		
31	Insulin	MW=34,000[6]; MP=223; IEP=5.3; s.w., sl.; pptd. by protein precipitants; stable acid; destroyed by alk.	Islets of Langerhans (various species).	Convulsions, (mice); hypoglycemia (starved rabbit); ↑ blood glucose (adrenodemedullated, hypo-x, diabetic rats).	
			Adrenal Medulla		
32	Epinephrine; adrenalin, suprarenine, adrenine	MW=183; MP(±)=207–211; $[\alpha]_D$ = -50° to -53.5°; s. alk. ac.; sl. s. w.; v. sl. s. el.; i. eth., chl.	Adrenal medulla; synth. (commerc.) catechol; in vivo, tyrosine; methylation of nor-epinephrine.	Stimulation isolated heart (frog); relaxation uterus (cat); dilatation pupil (cat); ↑ peristalsis (rabbit); ↑ BP (cat).	Cathechol derivatives.
33	Nor-epinephrine; arterenol, noradrenalin	MW=169; MP(±-bitart.)=163–164, ℓ-HCl=146–147; solubility as to epinephrine.	Adrenal medulla; various nerves, especially splenic; spleen, heart, blood vessels.	↓ epinephrine in rat testis except pressor and contraction of gravid uterus.	Methylated to epinephrine by adrenals in presence of ATP.
			Gastrointestinal Tract		
34	Cholecystokinin; CCK	MW=45,000–10,000(?); IEP=5.0–5.5; dialyzable, s. w.	Upper intestinal mucosa.	Contraction of gall-bladder (dog).	
35	Enterocrinin	s.ac., w., sl.; i. eth., acet.; salted out by NaCl.	Intestinal mucosa (hog, cat, dog, cow, man).	↑ flow of intestinal juice in jejunum (dog).	Metabolized as protein(?).
36	Enterogastrone	s.w.; i. org. solv.; dialyzable; destroyed by pepsin.	Duodenal mucosa.	↓ stim. effect of exogenous histamine on HCl secretion.	Urogastrone (?).
37	Gastrin	IEP=8; heat stable; destroyed by UV, alk., pepsin; dialyzable.	Gastric mucosa, especially pylorus.	No standard assay method.	
38	Pancreozymin	Salted out by NaCl; s. absolute sl.i., w.	Upper intestinal mucosa.	Increase in enzymes in pancreatic juice.	Unknown.
39	Secretin	MP=234; salted out by NaCl, CCl_3COOH; s. dilute acidic w.		Volume of pancreatic juice (dog).	
40	Urogastrone	Similar to enterogastrone; not destroyed by pepsin.[7]	Urine.	⇌ enterogastrone.	
			Neuro		
41	Acetylcholine; ACh; [Br] Pragmoline; [Cl] Acecoline	MW=163; MP (Br)=143; quart. salt unstable; s. w., al., eth., oils; salts v. s. w.; i. eth.	Ganglia of parasymp. nervous system; brain; synth. commercially.	None.	

/1/ ac. = acid; acet. = acetone; al. = alcohol (ethanol, 95%); alk. = alkali; aq. = aqueous; ba. = benzene; chl. = chloroform; diox. = dioxane; eth. = ether; HCG = human chorionic gonadotropic; i. = insoluble; IEP = isoelectric point; me. al. = methyl alcohol; MP = Melting Point; MW = molecular weight; org. = organic; PMS = pregnant mare serum; pptd. = precipitated; s. = soluble; sl. = slightly; sol. = solution; solv. = solvents; synth. = synthesized; v. = very; vol. = volatile; w. = watery wt. = weight; -x = -ectomized (e.g., hypo-x = hypophysectomized). /4/ Evidence for 2 fractions of TSH: (1) stimulation hypertrophy of acinar cells and colloid secretion from gland; (2) acceleration I^- uptake from blood, hormone synthesis. /5/ Circulating hormone probably thyroxin protein. Thyroglobulin (MW 650,000 and IEP 5) isolated from gland; circulating hormone may be 1/4 of this. Triiodothyronine is probably the tissue active compound; it is 5-7 times as potent as thyroxine. /6/ A polymer of 6 units of MW about 6000. /7/ Only the motor-inhibitory effect.

Part II: BIOLOGICAL PROPERTIES

Numbers in brackets refer to hormones listed in Part I.

↓ = decreased; ↑ = increased; (S) = stimulated; PMS = pregnant mare serum.

Hormone Number	Targets	Principal Effects	Effect of Deficiency (-) Excess (+)	Secretion Inhibited by (I) Stimulated by (S)
		Adrenal Cortex		
1 [1]	See [3, 4] ; chiefly kidneys, interstitial fluid; (mineralo-corticoid).	Promotes renal excretion of K, and retention of Na and Cl; 25-100 times more potent than [2]. Some properties of gluco-corticoids (q.v.).	- Hemoconcentration; ↑ Na, H_2O (blood, muscle); ↓ K retention. + Reverse of above; hypertension; congestive heart failure.	(S) low blood Na (?).
2 [2]	Same as [1]. (mineralo-corticoid).	Similar to [1].	Similar to [1], but effects much less pronounced.	
3 [3]	Muscles, liver, capillaries, kidneys, pancreas(?), integument, lymphoid organs and bone marrow, circulating blood cells; (gluco-corticoid).	Effects of gluco-corticoids [3, 4, 5, 6] are qualitatively comparable but differ quantitatively as follows: for glycogen deposition in liver, muscle work performance, hypersensitivity reactions, and thymus involution, the relative potencies are [5] =1.5, [6] =1.0, [3] =0.5, [4] =0.5; gluconeogenesis, [5] >[4] =[3] ; maintenance of renal function, [1] >[2] >[4] ≠[3] > [5] ≠[6] ; K/Na ratio and H_2O balance, [1] >[2] >[4] ≠[3] ; recovery muscular fatigue, [2] >[3] >[5] >[6] ; cold protection, [6] >[4] >[3] >[2] ; CHO metabolism, [5] > [3] >[2] ; collagen maintenance, [6] ; anti-inflammatory, [5, 6, 9] ; normal capillary permeability, [5, 6, 4]; protection against stress, [4, 5, 6] ; protection against shock, [2] .	- Asthenia; hemoconcentration; skin pigmentation; ↓ weight, blood glucose, liver glycogen, stress resistance, blood pressure; ↓ K/Na ratio in serum. + Reverse of above; Cushing's syndrome; hirsutism.	(S) ACTH.
4 [4]				
5 [5]	See [3, 4]; particularly muscle, liver, connective tissue; (gluco-corticoid).			
6 [6]				
7 [7]	Synthetic. More potent than [5, 6] in rheumatoid arthritis.			
		Ovaries		
8 [8]	All female sex organs; mammary glands; mucous membranes; anterior pituitary.	Estrogenic. Endometrial proliferation; development and maintenance of vaginal mucosa, cornification of superficial layers; antagonizes androgen effects; ↓ development mammary gland ducts, uterine motility, growth axillary and pubic hair (♀ human), growth of down (♀ bird), growth all ♀ secondary sex organs, estrus. Potency [10] >[12] >[11].	Unknown.	
9 [9]				
10 [10]			- ↓ development accessory sex organs, mammary glands, secondary sex characteristics, and ♀ behavior pattern. + Precocious maturity; hypertrophy accessory sex organs and mammary glands; precocious epiphyseal maturation and closure; estrus changes; cystic hyperplasia of endometrium.	(S) LH; FSH + LH (?).
11 [11]				
12 [12]				
13 [13]	Uterus; mammary glands.	Luteinizing. Preparation of endometrium for implantation of zygote; ↑ uterine contractions; ↓ development mammary glands, ↑ metabolism and secretion of estrogens.	- ↓ uterine motility and bleeding; abortion. + Prolongation of cycle; dysmenorrhea (?); ↑ Na, H_2O retention.	(S) LTH (?).
14 [14]	Pelvic ligaments.	Relaxation pelvic ligaments.	(?)	(S) estrogens (?).
		Placenta		
15 [15]	Ovaries (pregnancy, man and horse).	Maintenance corpus luteum in pregnancy; HCG = luteinizing corpus luteum; PMS = luteinization, follicle development.	- Abortion. + Toxemias of pregnancy (?).	(I) sex steroids.
		Testes (and Androgens from Urine)		
16 [16]	All male sex organs; anterior pituitary; muscle.	Androgenic. ↑ development ♂ secondary sex organs and sex characteristics, BMR, protein anabolism, retention Na and K, folliculoid and luteoid activity (♀ immature); ↑ creatinuria.	- ↓ development ♂ sex organs and sex characteristics, excretion 17-ketosteroids in urine. + Precocious sex development; rapid body growth; ↑ scalp hair (?); ↑ hirsutism; ↑ excretion 17-ketosteroids.	(I) sex steroids.
17 [17]				
18 [18]				
19 [19]	Seminiferous tubules.	↓ spermatogenesis even in hypophysectomized or folliculoid-overdosed animals.	(?).	
		Anterior Pituitary		
20 [20]	Adrenal cortex.	↑ lipid and ascorbic acid content of adrenal cortex; ↑ secretion adrenal cortical hormones.	- Atrophy and hypofunction of adrenal cortex; ↑ response to stress. + Hyperfunction adrenal cortex.	(I) circulating adrenal cortex hormones. (S) stress; epinephrine(?).
21 [21]	Ovarian follicles; seminiferous tubules.	↑ spermatogenesis and growth seminiferous tubules, development follicles (not ova production or estrogen secretion unless ICSH present).	- Obesity; ↑ H_2O metabolism, ovarian dysfunction. + No syndrome associated with FSH alone.	(I) circulating androgens and/or estrogens. (S) castration; low blood level of androgens and/or estrogens.
22 [22]	Bones, especially epiphyseal cartilage; most tissues.	↑ skeletal and soft-tissue growth, protein anabolism; ↑ pancreatic insulin (↓ in rat), maintenance muscle growth.	- Dwarfism and/or infantilism; delayed closure epiphyses. + Gigantism and/or acromegaly; hypertrophy of viscera'.	(I) estrogens or androgens (large doses).
23 [23]	Maturing Grasafian follicles and interstitial cells (ovarie's); interstitial cells of Leydig (testes).	↑ follicle maturation (production but not maintenance corpus luteum), secretion estrogens, and androgens from testes.	- ↓ ovulation; atrophy of Leydig cells. + Secretion estrogens and androgens; precocious development or ovulation.	(S) high blood level of ovarian and testicular hormones.
24 [24]	Mammary glands; crop-sac (pigeon); ovarian corpus luteum.	↑ milk secretion, progesterone secretion by developed corpus luteum, uterine nidation and decidua, growth and secretion of crop gland (pigeon).	- ↑ milk secretion, progesterone. + ↑ milk secretion.	(I) or (S) by effects of androgens, FSH; ICSH, and progesterone on target organs.
25 [25]	Thyroid gland	↑ synthesis and secretion of thyroid hormone, cell height of thyroid epithelium, thyroid size, serum protein bound iodine; ↑ iodine and colloid content of thyroid.	- Myxedema; cretinism (some forms); ↓ BMR. + Goiter; hyperthyroidism; ↑ BMR; exophthalmos?.	(I) ↓ circulating TH; (I) or (S) by nervous system. (S) ↑ circulating TH.

/1/ More characteristic of acromegaly, since long bones do not lengthen. /2/ May be caused by "exophthalmos factor" that can be separated from TSH.

Part II: BIOLOGICAL PROPERTIES (Concluded)

Numbers in brackets refer to hormones listed in Part I.

↓ = decreased; ↑ = increased; (S) = stimulated.

Hormone Number	Targets	Principal Effects	Effect of Deficiency (-) Excess (+)	Secretion Inhibited by (I) Stimulated by (S)
Pituitary Intermediate Lobe				
26 [26]	Chromatophore cells in skin of lower vertebrates	Expands chromatophores = pigment granules to disperse and color skin.	- Contraction chromatophores; ↓ skin pigment. + ↑ skin pigmentation, melanin synthesis; hyperglycemia.	(S) central nervous system; ACTH (chromatophore expansion).
Posterior Pituitary				
27 [27]	Uterine and other smooth muscles; mammary glands	Stimulates contraction uterine muscle, (and other smooth muscles too lesser degree), milk secretion.	- Delayed uterine contraction (pre- or postpartum); ↓ milk flow. + ↑ milk flow; abortion (?).	(S) suckling (?).
28 [28]	Capillaries; arterioles; coronary vessels; kidney vascular bed and tubules	↑ kidney excretion of H_2O[3]; ↓ excretion of NaCl and urea, ↓ blood pressure (constriction of capillaries).	- Diabetes insipidus[3]; ↑ excretion NaCl and urea. + ↓ H_2O retention.	(S) ↓ plasma osmotic conc. (I) ↑ plasma osmotic conc.
Parathyroid				
29 [29]	Bones; kidneys	Controls Ca and PO_4 level in blood via mineral exchange between blood and bones, and PO_4 excreted by kidneys.	- Tetany; convulsions; coma; death; ↓ Ca, ↑ PO_4 (serum); muscle spasm; cataract, scaly skin, hair loss (?). + ↑ PO_4, ↓ Ca (serum); ↓ alkaline phosphatase, excretion PO_4; decalcification bones; renal calcification.	(S) low Ca, high PO_4 diet; ↑ serum PO_4, ↑ serum Ca (?).
Thyroid				
30 [30]	All body cells	↓ oxidations; regulation of rate of CHO, fat, protein, H_2O, mineral metabolism; stimulates growth, maturation, neuromuscular function, skin development, hematopoiesis, spermato- and oogenesis, lactation; regulation of TSH secretion.	- Myxedema; cretinism (some types in fetus, child); retardation of ossification and epiphyseal maturation. + Hyperthyroidism; Grave's disease; exophthalmos.[2]	(I) anti-thyroid drugs, (S) TSH.
Pancreas				
31 [31]	Skeletal muscle; probably adipose tissue	Regulation CHO metabolism; ↓ oxidation tissue glucose (hexokinase) (?); ↑ glucogenesis, ↑ ketogenesis (indirect) (?).	- Diabetes mellitus (hyperglycemia, glycosuria, ketonuria; ↓ weight and blood volume; - nitrogen balance); delayed wound healing; gangrene. + Hyperinsulinism (hypoglycemia, convulsions, nausea, muscular weakness, anxiety and confusion).	(I) Pituitary extracts; GH; in tissues by epinephrine, glucocorticoids. (S) ↑ blood glucose; vagus stimulation.
Adrenal Medulla				
32 [32]	Sympathetic nervous system; heart muscle; smooth and skeletal muscles; liver	↓ contraction heart muscle (↓ output and rate), spleen, gravid uterus, iris muscle (radial), capillaries; relaxation non-gravid uterus, peripheral arterioles, bronchial muscles; ↑ peristalsis; ↑ glucogenolysis, BMR, blood coagulation; stimulates secretion ACTH (?); salivary, sweat glands.	- No clinical syndrome. + Over-secretion rare; may cause paroxistic hypertension, and, in some instances, sustained hypertension.	(S) sympathetic nervous system, via splanchnic nerve; "stress."
33 [33]	See [32]	Similar to [32], but causes arteriole constriction, hyperglycemia; no effect on cardiac output; pressor effect is not reversed by ergotoxine (as is that of [32]).		
Gastrointestinal Tract				
34 [34]	Gallbladder	Stimulates contraction and emptying of gallbladder.	(?)	(S) fat, protein, acid in duodenum.
35 [35]	Secretory cells of ileum, jejunum	↑ secretion succus entericus, volume rate and enzyme concentration.		(S) food in intestine.
36 [36]	Stomach	↓ motor activity and acid secretion of stomach.		(S) sugar, fat in intestine.
37 [37]	Parietal (HCl-producing) cells, stomach	↓ HCl secretion (but not pepsin) by gastric mucosa.		(S) mechanical distention; protein degradation products.
38 [38]	Enzyme-secreting cells of pancreas	↓ enzyme secretion by pancreas; no effect on volume rate.		(S) Peptones, amino acids, soaps, fats in duodenum.
39 [39]	Pancreas (acinar or exocrine), liver	↓ volume rate of pancreatic enzymes; no effect on concentration; stimulates bile secretion.	- Hyposecretion pancreatic enzymes and bile. + Excess doubtful.	(S) HCl, protein degradation products, digested fat or bile in small intestine.
40 [40]	Gastric mucosa and muscularis	↑ HCl secretion, muscular contractions stomach.		
Neuro				
41 [41]	Muscles, especially involuntary (ACh released at neuromuscular junctions, synapses)	Conduction electrical impulses along nerve fibers; ↑ heart rate; dilation arterioles; effects (cholinergic) generally opposite to those of epinephrine (adrenergic).	(?)	

[2] May be caused by "exophthalmos factor" that can be separated from TSH. [3] Antidiuretic hormone (ADH) fraction.

	Generic Name [Trade Name]	Structural Formula	Molecular Formula [Molecular Weight]	Solubility[1]	Mouse LD_{50} mg/kg	Benadryl Ratio[2]	Anesthesia min[3]	Atropine Ratio[4]	Epinephrine Potentiation[5]	Side Effects[6]
1	Diphenhydramine HCl [Benadryl]		$C_{17}H_{21}NO \cdot HCl$ [291.81]	s.w., al., chl.; sl.s. bz., eth.	31(IV) 83(IP) 206(PO) 129(SC)	1.0(a, b, c, d, e)	22	0.02	Yes	Sedation, dizziness, dry mouth, lassitude, excitement, nausea.
2	Antazoline HCl [Antistine]		$C_{17}H_{19}N_3 \cdot HCl$ [301.82]	s.al.; sl.s. w., il.bz., eth.	39(IV-rats) 150(IP)	0.1(a) 0.5(b)	20	<0.001	No	Dry mouth, headache, tachycardia, nervousness, nausea.
3	Bromodiphenhydramine HCl [Ambodryl]		$C_{17}H_{20}BrNO \cdot HCl$ [370.73]	s.w.	108(IP)	1.4(a) 2.2(b)		0.005	Yes	Dizziness, anorexia, dry mouth, diarrhea.
4	Carbinoxamine maleate [Clistin]		$C_{16}H_{19}ClN_2O \cdot C_4H_4O_4$ [406.86]	s.w., al., chl.; sl.s. eth.	411(PO)	24.0(e)	0	Weak	No	Somnolence, dizziness, dry mouth, gastric pain.
5	Chlorcyclizine HCl [Perazil]		$C_{18}H_{21}ClN_2 \cdot 2HCl$ [373.57]	s.w., chl., al.; il.bz., eth.	137(IP)	1.0(a) 7.0(b) 4.0(d)	22	Moderate	Yes	Dry mouth, headache, blurred vision, insomnia, palpitation, gastric disturbances.
6	Chlorothen citrate [Chlorothen; tagathen]		$C_{14}H_{18}ClN_3S \cdot C_6H_8O_7$ [487.95]	s.w.; sl.s. al., eth.	26(IV) 105(IP)	10.0(a)		0.01		Sedation, dizziness, headache, gastric disturbances.
7	Chlorphenirsmine maleate [Chlortrimeton]		$C_{16}H_{19}ClN_2 \cdot C_4H_4O_4$ [390.86]	s.w., al., chl.; sl.s. bz., eth.	40(IV) 77(IP) 176(PO) 104(SC)	3.0(a) 29.0(b) 35.0(e)	15	0.001	Yes	Jitteriness, dry mouth, gastric disturbances.
8	Doxylamine succinate [Decapryn]		$C_{17}H_{22}N_2O \cdot C_4H_6O_4$ [388.45]	s.w., al., chl.; sl.s. bz.	62(IV) 470(PO) 460(SC)	1.0(a) 2.5(e)	16	<0.001		Sedation, dizziness, headache, dermatitis, gastric disturbances.
9	Methaphenilene HCl [Distrin]		$C_{15}H_{20}N_2S \cdot HCl$ [296.86]	s.w.; sl.s. al., chl.; i. eth.	117(IP)	1.7(a) 1.3(b)		0.007		Irritability, burning of the skin, gastric disturbances.
10 11	Methapyrilene (Thenylpyramine) HCl [Thenylene; Histadyl]		$C_{14}H_{19}N_3S \cdot HCl$ [297.85]	s.w., al.; i.bz., eth.	20(IV) 77(IP) 182(PO)	5.0(a) 4.0(b)	17	0.002	Yes	Dizziness, dry mouth, headache, nervousness, nausea.

/1/ Abbreviations: al. = alcohol (ethanol 95%); bz. = benzene; chl. = chloroform; eth. = ether; glyc. = glycerol; i. = insoluble; s. = soluble; sl. = slightly; w. = water. /2/ Benadryl Ratio as based on: (a) isolated guinea pig ileum; (b) bronchoconstrictor effect of histamine aerosol in guinea pigs; (c) vasodepressor response to histamine in dogs; (d) guinea pig tracheal chain; (e) bronchoconstrictor effect of intravenous histamine in guinea pig s. /3/ Corneal local anesthesia duration in rabbits or guinea pigs, using 1% solution. /4/ Anticholinergic effect on isolated rabbit intestine. /5/ Potentiation of epinepherine pressor effect. /6/ In addition to drowsiness, which is a side effect common to all drugs listed.

	Generic Name [Trade Name]	Structural Formula	Molecular Formula (Molecular Weight)	Solubility[1]	Mouse LD_{50} mg/kg	Benadryl Ratio[2]	Anesthesia Ratio[3]	Atropine Ratio[4]	Epinephrine Potentiation[5]	Side Effects[6]
12	Phenindamine tartrate [Thephorin]		$C_{19}H_{19}N \cdot C_4H_6O_6$ [297.82]	s.w.;sl.e. propylene glycol; i. al., glyc., eth.	23(IV) 88(IP) 280(PO) 300(SC)	2.0(b) 9.3(d)		0.003	No	Dizziness, headache, anorexia, palpitations, restlessness, depression, nausea.
13	Pheniramine maleate [Trimeton]		$C_{16}H_{20}N_2 \cdot C_4H_4O_4$ [356.41]	s.w., sl.; sl.s.bz., eth.	60(IV) 65(IP) 225(PO) 132(SC)	2.0(b) 1.3(d) 2.0(e)	0	<0.001	Yes	Dry mouth, weakness, gastric disturbance.
14	Phenyltoloxamine HCl [Bristamin]		$C_{17}H_{21}NO \cdot HCl$ [291.82]	s.w.	33(IV) 163(IP) 424(PO)	1.1(b)	Same as procaine q. v.	0.01	No	Dry mouth.
15	Promethazine HCl [Phenergan]		$C_{17}H_{20}N_2S \cdot HCl$ [320.88]	s.w., al., chl.	55(IV) 200(PO) 190(IP)	2.5(a) 4-10(b)	69	Moderate	Yes	Dizziness, weakness, dry mouth, nausea, vomiting.
16	Pyrathiazine HCl [Pyrrolazote]		$C_{18}H_{20}N_2S \cdot HCl$ [332.89]	s.w., al.	37(IV) 465(PO) 1340(SC)	4.0(a) 4.0(b)	53	0.004	No	Headache, nausea.
17	Pyrrlamine maleate [Neoantergan]		$C_{17}H_{23}N_3O \cdot C_4H_4O_4$ [401.45]	s.w., sl.; al.s.bz., eth.	30(IV) 102(IP) 150(SC)	10.4(a) 28.0(b) 1.0(c) 17.1(d)	21	0.002	Yes	Vertigo, dry mouth, nervousness, headache, nausea.
18	Pyrrobutamine phosphate [Pyronil]		$C_{20}H_{22}ClN \cdot 2H_3PO_4$ [507.86]	s.h.w.	54(IV) 1116(PO) 1270(SC)	14.0(a) 20.0(b)	92	Weak		Dizziness, dry mouth, headache, palpitation, nervousness, nausea, diarrhea.
19	Thenyldiamine HCl [Thenfadil]		$C_{14}H_{19}N_3S \cdot HCl$ [297.85]	s.w.;sl. s.al.	14(IV) 55(IP) 277(PO) 36(SC)	1.0(c)		0.0025		
20	Thonzylamine HCl [Neohetramine]		$C_{16}H_{22}N_4O \cdot HCl$ [322.83]	s.w., al., chl., i. eth.	119(IP) 245(PO)	1.0(b) 4.0(d)	Same as procaine q. v.	Weak	No	Dry mouth, headache, nervousness, nausea.
21	Tripelennamine HCl [Pyribensamine]		$C_{16}H_{21}N_3 \cdot HCl$ [291.82]	s.w., al., chl.; i. bz., eth.	16(IV) 74(IP) 210(PO) 71(SC)	5.0(a) 6.5(b) 5.0(c) 5.1(d) 1.0(e)	17	0.0025	Yes	Dizziness, dry mouth, headache, excitement, gastric disturbances.

/1/ Abbreviations: al. = alcohol (ethanol 95%); bz. = benzene; chl. = chloroform; eth. = ether; glyc. = glycerol; i. = insoluble; s. = soluble; sl. = slightly; w. = water. /2/ Benadryl Ratio as based on: (a) isolated guinea pig ileum; (b) bronchoconstrictor effect of histamine aerosol in guinea pigs; (c) vasodepressor response to histamine in dogs; (d) guinea pig tracheal chain; (e) bronchoconstrictor effect of intravenous histamine in guinea pigs. /3/ Corneal local anesthesia duration in rabbits or guinea pigs, using 1% solution. /4/ Anticholinergic effect on isolated rabbit intestine. /5/ Potentiation of epicopherine pressor effect. /6/ In addition to drowsiness, which is a side effect common to all drugs listed.

Blood levels and dosages indicated in this table are not to be interpreted as recommendations of the National Academy of Sciences - National Research Council, nor does the appearance of a trade name imply such endorsement for the product or its manufacturer. These are presented for informative purposes only.

	Therapeutic Agent	Common or Trade Name	Use	Dosage	Route of Administration[1]	Minutes After Administration[2]	Blood Concentration[3] mg/100 ml[2]
			Antibiotics				
1	Chloramphenicol	Chloromycetin	Infections caused by G+ and G- bacteria, viruses.	0.5 g	O	30	0.4(P)
2	Chlorotetracycline HCl	Aureomycin HCl	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg(P)
3	Erythromycin		Infections caused by G+ bacteria.	300 mg	O	60-120	0.015 mg
4	Oxytetracycline	Terramycin	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg(P)
5	Penicillin G procaine		Infections caused by G+ bacteria.	300,000 units	IM	60-180	0.06 mg(S)
6	Tetracycline	Achromycin	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg(P)
			Antihistamines				
7	Diphenhydramine HCl	Benadryl HCl	Histamine antagonist.	50 mg	O	15-30	
8	Tripelennamine HCl	Pyribenzamine HCl	Histamine antagonist.	50 mg	O	15-30	<300 µg(P)
			Antimalarial Drugs				
9	Chloroquine di-PO_4	Aralen-SN 7618	Suppressive, therapeutic.	1 g (start); 500 mg (6 hr); 500 mg (2nd, 3rd da)[4]	O	Slow	0.015-0.020 mg (P)
10	Pyrimethamine	Daraprim	Suppressive antimalarial.	100 mg[5]	O	60-120	0.08-0.16
11	Quinacrine HCl	Atabrine	Suppressive, therapeutic.	200 mg (every 6 hr for 5 doses); then 100 mg (3 times daily for 6 da)[4]	O	Slow	0.002-0.003 mg (S)
			Antituberculosis Drugs				
12	Isoniazid		Tuberculosis therapy.	100 mg	O	120-180	0.13-0.34(P)
13	Para-amino-salicylic acid	PAS	Tuberculosis therapy.	4 g	O	30-60	10
14	Streptomycin SO_4		Tuberculosis therapy; infections caused by G- bacteria.	500 mg	IM	30-180	0.7-1.5(P)
			Autonomic Nervous System Drugs				
15	Atropine SO_4		Parasympatholytic.	0.5 mg	O	15	
16	Bethanechol Cl	Urecholine	Parasympathomimetic.	20 mg	O	30	
17	Ephedrine SO_4		Sympathomimetic.	25 mg	O, SC	20	
18	Epinephrine HCl	Adrenalin	Sympathomimetic.	0.5 mg	SC	5	
				2 mg	IM	5	
19	Neostigmine Br	Prostigmine Br	Parasympathomimetic.	15 mg	O	15	$9x10^{-3}$ (P)
20	Priscoline		Sympatholytic.	25 mg	O	15	<1
			Cardiovascular Drugs				
21	Aminophylline		Angina pectoris, coronary thrombosis, asthma.	200 mg	O	30-60	0.3-0.4 as theophylline
22	Digitoxin		Cardiac decompensation.	0.1 mg	O	30-120	<1 µg
23	Glyceryl trinitrate	Trinitroglycerine	Angina pectoris.	0.4 mg	SL	2-5	
24	Quinidine SO_4		Auricular fibrillation.	200 mg	O	60-120	0.2-0.4 mg
			Central Nervous System Depressants				
	Analgesics, hypnotics, and sedatives						
25	Acetophenetidine	Phenacetin	Analgesia.	300 mg	O	15-30	>0.1 (P)
26	Acetylsalicylic acid	Aspirin	Analgesia.	600 mg	O	15-30	2-3 (P)
27	Amobarbital sodium	Amytal sodium	Hypnosis.	100 mg	O	30	0.6-0.8
28	Codeine phosphate		Analgesia.	30 mg	O	30	
29	Meperidine HCl	Demerol	Analgesia.	100 mg	IM	15-30	0.125 (P)
30	Methadone	Amidone; Dolophine	Analgesia.	7.5 mg	O or SC	15-30	
31	Morphine SO_4		Analgesia.	15 mg	O or SC	15-30	250 µg
32	Paraldehyde		Analgesia[6].	4 (1-30) g[7]	R or O	30	11.8-24.4(S)
33	Pentobarbital sodium	Nembutal sodium	Hypnosis.	100 mg	O	15	0.2-0.3
34	Phenobarbital sodium	Luminal sodium	Sedation.	30 mg	O	30	5
35	Secobarbital sodium	Seconal sodium	Hypnosis.	100 mg	O	15	0.2-0.3
36	Sodium bromide		Sedation.	1 g	O	60	16-50
	Anesthetics						
37	Chloroform		Surgical anesthesia.	1.5 vol %	I	5	15-20
38	Cyclopropane		Surgical anesthesia.	20-30 vol %	I	2-3	15
39	Ether, ethyl		Surgical anesthesia.	6-10 vol %	I	15-20	50-130
40	Ether, ethyl vinyl	Vinamar	Surgical anesthesia.	6 vol %	I	2-4	50
41	Ether, methyl-n-propyl	Neothyl	Surgical anesthesia.	2.5-3 vol %	I	10-15	30-60
42	Ether, vinyl	Vinethene	Surgical anesthesia.	4 vol %	I	1-2	28
43	Ethyl alcohol		Euphoria.	30 ml	O	15-30	30
44			Hypnotic.	100 ml	O	15-30	100
45			Anesthesia (stupor).	300-400 ml	O	15-30	300-400
46	Ethyl chloride		Surgical anesthesia.	3-4.5 vol %	I	2	20-30
47	Ethylene		Anesthesia (Plane 1).	80-85 vol %	I	20	120-180
48	Nitrous oxide		Anesthesia (Plane 1).	85-92 vol %	I	2	23 vol %
49	Thiamylal sodium	Surital sodium	Short surgical procedures.	3-6 ml of 2.5% solution[8]	IV	1-10	1.5-2
50	Thiopental sodium	Pentothal sodium	Short surgical procedures.	2-3 ml of 2.5% solution[9]	IV	1-10	1.5-2
51	Tribromethenol (soln)	Avertin	Basal anesthesia.	80-100 mg/kg	R	30	6-9
	Anticonvulsants						
52	Diphenylhydantoin sodium	Dilantin	Anti-epileptic.	100 mg[10]	O	2-3 da	3-6
53	Trimethadione	Tridione	Anti-epileptic.	300 mg[11]	O	2-3 da	4-6(P)
			Central Nervous System Stimulants				
54	Caffeine		Central stimulant.	200 mg	O	15-30	0.1-0.2(P)
55	Dextroamphetamine SO_4	Dexedrine	Central stimulant.	5 mg	O	30	Not available
56	Pentylenetetrazol	Metrazol	Respiratory stimulant.	100 mg	IV, SC	5-15	Not available

[1] Inhalation; IM=intramuscular; IV=intravenous; N=nasal; Ovoral; PA = parenteral; Rrectal; SC=subcutaneous; SL=sublingual. [2] Unless otherwise indicated. /3/ (P)=plasma; (S)=serum. /4/ Therapeutic dose. /5/ Usual dose, 25 mg. /6/ Also as anti-convulsant and in alcoholic psychoses. /7/ Range, depending upon use. /8/ At rate of 1 ml per 5 sec. /9/ In 15 sec; repeat in 30 sec as required. /10/ 2-4 times per day. /11/ 3-6 times per day.

336. THERAPEUTIC AGENTS: EFFECTIVE BLOOD LEVELS (Concluded)

Blood levels and dosages indicated in this table are not to be interpreted as recommendations of the National Academy of Sciences - National Research Council, nor does the appearance of a trade name imply such endorsement for the product or its manufacturer. These are presented for informative purposes only.

	Therapeutic Agent	Common or Trade Name	Use	Dosage	Route of Administration[1]	Minutes After Administration[2]	Blood Concentration[3] mg/100 ml[2]
			Diuretics				
57	Acetazoleamide	Diamox	Diuretic.	250 mg	O	60-120	
58	Meralluride	Mercuhydrin	Diuretic.	1 ml[12]	PA	180	Not available
59	Mercaptomerin sodium	Thiomerin	Diuretic.	130 mg (in 1 ml)	PA	180	Not available
			Hematopoietic Drugs				
60	Ferrous sulfate		Secondary anemia.	300 mg	O	Variable	105 µg as Fe (P)
61	Vitamin B_{12}		Pernicious anemia.	15 µg	IM	60	
62	Corticotropin		Adrenocorticotropic hormone.	10 U.S.P. Units[13]	IV	Slow	
63	Cortisone acetate		Collagen diseases.	25 mg[14]	O	Slow	
64	Diethylstilbestrol		As estrogen.	0.5 mg	O	Slow	
65	Hydrocortisone acetate		Collagen diseases.	10 mg[10]	O	Slow	
66	Insulin(a)		Diabetes.	No official dose	SC	60-360[15]	
67	Methyltestosterone		As androgen.	10 mg	O or SL	Slow	
68	Thyroxine		Mild hypothyroidism.				
			Sulfonamides				
69	Sulfadiazine		Antibacterial.	4 g[16]	O	180-240	8, free form
70	Sulfamerazine		Antibacterial.	4 g[16]	O	180-240	9.8, free form
71	Sulfamethazine		Antibacterial.	4 g[16]	O	180-240	7.8, free form
72	Sulfasoxazole		Antibacterial.	4 g[16]	O	180-240	6-8, free form
			Vitamins				
73	Ascorbic acid	Vitamin C	Vitamin deficiency.	75 mg[17]; 150 mg[18]	O	Readily	1-2(P)
74	Nicotinic acid		Vitamin deficiency.	100 mg	O	Slow	
75	Riboflavin	Lactoflavin, Vitamins B_2 and G	Vitamin deficiency.	3 mg[17]; 5 mg[18]	O	Readily	
76	Thiamine HCl	Vitamin B_1	Vitamin deficiency.	25 mg	O	Readily	
77	Vitamin A		Vitamin deficiency.	25,000 Units[18] (adult)	O	Slow	0.03 mg; vitamin A alcohol
78	Vitamin D, oleo- (synthetic)		Vitamin deficiency.	50,000 U.S.P. Units	O	Slow	5×10^{-4}
			Miscellaneous				
79	Carbarsone		Amebic dysentery.	250 mg	O		

/1/ I=inhalation; IM=intramuscular; IV=intravenous; N=nasal; Oworal; PA = parenteral; R=rectal; SC=subcutaneous; SL=sublingual. /2/ Unless otherwise indicated. /3/ (P)=plasma; (S)=serum. /10/ 2-4 times per day. /12/ Equivalent to 39 mg Hg and 45 mg theophylline. /13/ In 8 hr infusion. /14/ Four times daily. /15/ Dependent on type. /16/ Initial dose. /17/ Requirement. /18/ Therapeutic dose.

337. BARBITURATES: PLASMA LEVELS AT AWAKENING

With each dosage administered, objective was to produce sleep. Plasma concentrations were determined at time of awakening. For many investigations this is the critical dose level, inasmuch as any significantly greater concentration would be a hypnotic or anesthetic level. Ranges, in parentheses, conform to estimate "b" of the 95% range (cf Introduction).

	Barbiturate	Animal	Dosage mg/kg[1]	Route of Administration[2]	Plasma[3] Concentration mg/100 ml
1	Barbital	Man	200	O	1.5
2		Man	600[4]	O	0.8[3]
3	Hexobarbital	Rat	100	IP	4.1
4	5-Isopropyl-5-(2-methylpentyl)-2-thiobarbiturate, sodium	Dog	21	IV	0.64(0.38-0.90)
5	Pentobarbital	Man	800[4]	O	0.8[3]
6		Man	2000[4]	O	1.0[3]
7		Man	750-1000[4]	IV	0.8[3]
8		Dog	20	IV	1.5(1.1-1.9)
9		Dog	25	IV	1.7(1.3-2.1)
10		Mouse	50	IP(?)	2.6
11		Rabbit	15	IV	1.0(0.8-1.2)
12		Rabbit	25	IV	1.0(0.6-1.4)
13		Rabbit	30	IV	1.2(0.8-1.6)
14		Rabbit	35	IP	1.2(0.4-2.0)
15		Rat	30	IP	2.9
16		Rat	60	IP	2.0
17	Phenobarbital	Man	(?)	O	1.2
18	Secobarbital	Man	600	O	0.8
19		Dog	20	IV	1.1(0.9-1.3)
20		Dog	25	IV	1.2(1.0-1.4)
21		Rabbit	15	IV	1.0(0.8-1.2)
22		Rabbit	25	IV	0.8(0.4-1.2)
23	Thiamylal	Dog	21	IV	0.95(0.83-1.07)
24	Thiothamyl[5]	Dog	20	IV	2.3(0.7-3.9)
25	Thiopental	Man	22	IV	1.3
26		Man	33	IV	1.7
27		Man	36	IV	2.3
28		Man	40	IV	1.9
29		Man	43	IV	2.0
30		Man	50	IV	2.6
31		Man	54	IV	2.5
32		Man	59	IV	3.3
33		Man	65	IV	2.7
34		Man	67	IV	2.8
35		Dog	10	IV	0.9[5]
36		Dog	20	IV	1.2(1.1-1.3)
37		Dog	25	IV	1.7[6]
38		Dog	30	IV	1.5[5]
39		Dog	35	IV	1.8[5]
40		Dog	40	IV	2.4[6]
41		Mouse	30	IV	3.2[6]
42		Mouse	45	IV	4.9[6]
43		Mouse	70	IP	2.7(2.3-3.1)
44		Mouse	70	IV	2.2[5]
45		Rabbit	25	IV	2.3(1.7-2.9)
46		Rabbit	27	IV	1.9(1.1-2.7)

/1/ Unless otherwise indicated. /2/ O = oral; IP = intraperitoneal; IV = intravenous. /3/ Approximate. /4/ Mg per individual. /5/ Estimated from graph. /6/ Serum.

Data in this table are only a representative sample of the voluminous literature on the subject.

Part I: EFFECTS ON MITOSIS AND MEIOSIS

	Compound	Organism, Part Affected	Effect
		Interphase	
1	Auxin	Cambium	Division stimulated.
2	Glucose	Mouse epidermis	
3	Hypoxanthine	Chick osteoblasts	
4	Indoleacetic acid	Onion root	
5	Acridines	Chick fibroblasts	Initiation of prophase inhibited.
6	Azaguanine	Mouse tumors	
7	Dyes	Frog sperm	
8	Nitrogen mustard	Animals	
9	Phenylacetic acid	Onion root	
10	Cortisone	Onion root	Chromosome doubling within nucleus.
11	Naphthaleneacetic acid	Bean internodes	
12	Folic acid antagonists	Mouse intestine	Pycnosis from prophase damage.
13	Hydroquinone	Mouse intestine	
14	Neotetrazolium	Onion root	
15	Urethane	Mouse intestine	
16	Trypaflavine	Onion root	Destruction of interphase nucleus.
		Prophase	
17	Dichlorophenoxyacetic acid	Onion root	
18	Nitrophenols	Sea urchin egg	Prophase blocked.
19	Protoanemonin	Corn root	
20	Glutathione	Amoeba proteus	Prophase accelerated.
21	Urethane	Rabbit fibroblasts	
22	Tropolones	Tradescantia stamen hairs.	Precocious chromosome split.
23	Trypan blue	Rabbit fibroblasts	Spindle formation slowed.
24	Aureomycin	Onion root	Membrane dissolution delayed.
25	Acridines	Onion root	Reversion to interphase.
26	Purines	Arbacia egg	
		Metaphase[1]	
27	Methylnaphthoquinone	Onion root	Abnormal chromosome orientation.
28	Testosterone, estrone	Rabbit fibroblasts.	
29	Diphenyl	Wheat root	Rotate spindle.
30	Indoleacetic acid	Wheat root	
31	Colchicine	Onion root	Induce monopolar mitotic figure.
32	Mustard gas	Chick osteoblasts	
33	Narcotics	Onion root	
34	Phenyl urethane	Sea urchin egg	
35	Carbamates	Sea urchin egg	Induce multipolar spindle.
36	Diethyl bromacetyl carbamide	Onion root	
37	Ethyl mercuric phosphate	Corn seedling	
38	Methylnaphthohydroquinone diacetate	Onion root	
39	Streptomycin	Onion root	Revert to interphase.
40	Alcohol	Onion root	Nucleolus reorformation.
41	DDT	Onion root	

	Compound	Organism, Part Affected	Effect
		Anaphase	
42	Caffeine	Onion root	Incomplete chromosome separation.
43	Kynadoine	Sea urchin egg	
44	Trypaflavine	Rabbit fibroblast	
		Telophase	
45	Aureomycin	Chick fibroblasts	Cytoplasmic division suppressed.
46	Caffeine	Onion root	
47	Carbamates	Sea urchin egg	
48	Nicotine	Tobacco anthers	
49	Quinone	Worm egg	
50	Rotenone	Sea urchin egg	
51	Sulfanilamide	Onion root	
52	Theobromine	Onion root	
53	Nicotine	Pea seedling	Spindle remnant persists.
54	Sulfhydryl compounds	Yeasts	Cytoplasmic division enhanced.
55	Chloracetophenone	Chick osteoblasts	Nuclear reconstruction retarded.
56	Thiourea	Chick fibroblasts	
		Chromosome Effects Not Confined to One Phase	
57	Acenaphthine	Onion root	Breaks.
58	Acridines	Onion root	
59	Coumarin	Onion root	
60	Phenols	Onion root	
61	Uracil	Onion root	
62	Urethane	Bean root	
63	Epoxides	Bean root	Rearrangement within chromosome.
64	Ethoxy caffeine	Onion root	
65	Mustards	Onion root	
66	Urethane	Peony buds	
67	n-Butyl gallate	Onion root	Adhesion.
68	Dyes	Onion root	
69	Acridines	Onion root	Pseudochiasmata.
70	Coumarin	Onion root	
71	Aminoacridine	Onion root	Chromatin diminished.
72	Aminobenzoate	Onion root	
73	Phenols	Onion root	
74	Ammonia	Tradescantia hairs	Dispersion and despiralization.
75	Ammonium thiocyanate	Impatiens pollen mother cells	
76	Urea	Drosophila salivary glands	
77	Glutathione	Worm regenerating tissues	Chromosome widened.
78	Antibiotics	Onion root	
79	Cysteine	Protozoa	Induced reduction.
80	Nucleic acid	Onion root	
81	Acenaphthene	Onion root	Centromere misdivision.
82	Mustard	Tradescantia pollen mother cells	

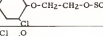
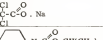
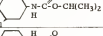
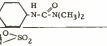
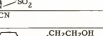
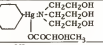
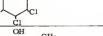
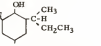
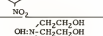
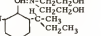
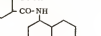
/1/ See Part 2 (below) for metaphase block.

Part II: MITOTIC POISONS: METAPHASE BLOCKING AGENTS

	Substance	Concentration	Animal	Tissue
1	Acenaphthine	Vapor	Drosophila melanogaster	
2	Aureomycin	100 ppm	Chick embryo	Fibroblast
3	Benzene		Mammal	Marrow
4	Colchicine	10^{-5} M	Chortophaga viridifasciata	Neuroblast
5	Coumarin	0.1%	Arbacia punctulata	Egg
6	DDT	Saturated	Arbacia punctulata	Egg
7	Dibenzanthracene	0.1%	Chick embryo	Fibroblast
8	p-Dichlorobenzene	Saturated	Paracentrotus lividus	Egg
9	Epinephrine	0.01%	Chick embryo heart	Fibroblast
10	Ethyl-p-aminobenzoate	Saturated	Paracentrotus lividus	Egg
11	Hexachlorocyclohexane	0.02%	Sphaerechinus granularis	Egg
12	Methyl anthranilate	Saturated	Paracentrotus lividus	Egg
13	Morphine	10^{-4} M	Chick embryo	Iris epithelium
14	Naphthoquinone	10^{-2} M	Tubifex	Egg
15	Nicotine	1/8000	Rabbit fibroblast	
16	Phenyl urethane	2×10^{-3} M	Strongylocentrotus lividus	Egg
17	Physostigmine	0.1%	Arbacia punctulata	Egg
18	Podophyllotoxin	10^{-4} mM	Echinarachnius parma	Egg
19	Sulfanilamide		Paracentrotus lividus	Egg

	Substance	Concentration	Plant	Tissue
20	Acenaphthine	Saturated	Colchicum	Root
21	Aureomycin	50 ppm	Allium cepa	Root
22	Benzene	Saturated	Allium sativum	Root
23	Colchicine	20%	Colchicum autumnale	Root
24	Coumarin	Saturated	Allium cepa	Root
25	DDT	Saturated	Allium cepa	Root
26	Dibenzanthracene	1.5 ppm	Secale cereale	Root
27	p-Dichlorobenzene	Vapor	Triticum vulgare	Root
28	Epinephrine	1/100	Tradescantia occidentalis	Pollen tube
29	Ethyl-p-aminobenzoate	M/400	Allium cepa	Root
30	Hexachlorocyclohexane	10^{-4} M	Cucurbita pepo	Root
31	Methyl anthranilate	Vapor	Linum usitatissimum	
32	Morphine	0.1%	Vicia lutea	Root
33	Naphthoquinone	10^{-2} M	Allium cepa	Root
34	Nicotine	Vapor	Nicotiana tabacum	Bud
35	Phenyl urethane	0.02%	Allium cepa	Root
36	Physostigmine	0.05%	Allium cepa	Root
37	Podophyllotoxin	Saturated	Allium cepa	Root
38	Sulfanilamide	1/2000	Allium cepa	Root

	Common and [Chemical Name]	Structure	Properties[1]	Solubility[2]	Oral Toxicity, Single Dose[3] LD_{50} mg/kg	Hazard to Humans[4]	Type of Activity
1	2, 4-D [2, 4-dichlorophenoxy-acetic acid]		MW=221.0;MP=139.2-140.5; BP=241$^{99.4}$;sp gr=1.565^{30}.	sl. s. w. (0.05%); i. oils; s. acet	375 rat;368 mouse; 541 chick;100 dog; 800 rabbit.	Injurious to eyes; dust, strong sol. irritating to skin, mucous membranes; not a sensitizer.	Systemic weed killer.
2	Methyl ester of 2, 4-D [methyl 2, 4-dichlorophenoxyacetate]		MW=235.0;MP=33-38;BP=119^{7}; sp gr=1.370$^{37.0/4}$.	i. w.,v. s. aromatic oils.	650 g. pig.	Very slight; concentrate causes transient injury to eyes, irritation to skin.	Systemic weed killer.
3	Isopropyl ester of 2,4-D [isopropyl 2,4-dichlorophenoxyacetate]		MW=263.1;MP=22.8(fr. p.); BP=170^{10};sp gr=1.251^{20} (com'l).	i. w.;s. kerosene; v. s. xylene.	700 rat; 541 mouse; 550 g pig;1420 chick.	Concentrate slightly irritating to skin upon prolonged contact.	Systemic weed killer.
4	n-Butyl ester of 2, 4-D [n-butyl 2, 4-dichlorophenoxyacetate]		MW=277.1;MP=9(fr. p.); BP=160-170$^{15-2}$;sp gr=1.235$^{25/4}$.	i. w.;s. kerosene; v. s. xylene.	620 rat; 848 g pig;424 rabbit.	Concentrate slightly irritating to skin upon prolonged contact.	Systemic weed killer.
5	Propylene glycol butyl ether esters of 2, 4-D [poly-propylene glycol butyl ether 2, 4-di-chlorophenoxyacetate]		MW=356(av.); liquid; sp gr=1.188^{20}.	i. w.;s. kerosene; v. s xylene.	570 rat.	Concentrate causes transient injury to eyes; slightly irritating to skin upon prolonged exposure.	Systemic weed killer.
6	2-Butoxyethyl ester of 2, 4-D [2-butoxyethyl 2, 4-dichlorophenoxy-acetate]		MW=321.2; liquid.	i. w.;s. kerosene; v. s. xylene.		Concentrate causes transient injury to eyes; slightly irritating to skin upon prolonged exposure.	Systemic weed killer.
7	Triethanolamine salt of 2, 4-D [2, 4-dichlorophenoxyacetic acid tri-ethanolamine salt]		MW=361-366^{5};MP=142-144; sp gr=1.237^{20}.	v. s. w.;i. oil.	2000 g. pig; 500# chick.	Injurious to eyes; irritating to skin upon prolonged contact.	Systemic weed killer.
8	2, 4, 5-T [2, 4, 5-trichlorophenoxyacetic acid]		MW=255.5;MP=153.5-155; sp gr=1.80^{20}.	sl. s. w. (0.02%); sl. s. oil.	500 rat; 389 mouse; 381 g. pig;100 dog.	Injurious to eyes; dust and concentrate irritating to skin, throat, lungs.	Systemic weed killer.
9	Methyl ester of 2,4,5-T [methyl 2, 4, 5-trichlorophenoxyacetate]		MW=269.5;MP=89-90.	i. w;sl. s. kerosene; s. xylene.			Systemic weed and woody plant killer.
10	Isopropyl ester of 2, 4, 5-T [isopropyl 2, 4, 5-trichlorophenoxyacetate]		MW=297.6;MP=42-43;BP=152^{2}-$^{0.5}$;sp gr=1.243-1.26^{20}.	i. w.;sl. s. kerosene;s. xylene.	495 rat;551 mouse;449 g. pig;850 chick.	Transient injury to eyes from concentrate; slightly irritating to skin upon prolonged contact.	Systemic weed killer.
11	Propylene glycol butyl ether esters of 2,4,5-T [poly-propylene glycol butyl ether 2, 4, 5-trichlorophenoxyacetate]		MW=390.5[av.];liquid;BP=193-200$^{2-.5}$;sp gr=1.24-1.25^{20}.	i. w.;s. kerosene; v. s. xylene.	890 rat;820 mouse;1000 g. pig; 360 rabbit; 2400 chick.	Transient injury to eyes from concentrate; slightly irritating to skin upon prolonged contact.	Systemic weed and woody plant killer.
12	MCPA [2-methyl-4-chlorophenoxyacetic acid]		MW=200.6;MP=119-120; sp gr=1.35^{15}.	sl. s. w.(0.1%); i. oil.	700 rat.	Injurious to eyes; concentrate slightly irritating to skin upon long contact.	Systemic weed killer.
13	Triethanolamine salt of MCPA [4-chloro-o-tolyoxyacetic acid tri-ethanolamine salt]		MW=340.6-345.6^{5};sp gr=1.206^{20}.	v. s. w.;i. oil.	1200 rat.	injurious to eyes; concentrate slightly irritating to skin upon long contact.	Systemic weed killer.
14	Maleic hydrazide (MH) [1, 2-dihydropyridazine-3, 6-dione]		MW=112;MP=290-295; sp gr=1.60^{15} (tech. grade).	sl. s. w. (0.6%); i. acet.	5800 rat.	No effect on eyes or skin.	Translocated.

15	2, 4-DES [sodium-2, 4-dichlorophenoxy-ethyl sulfate]		MW=309; MP=170; density approx. 27 lb/cu ft; purity=90% +.	s. w. (25%); i. oil.	730-1400 rat; 250 rabbit.	Injurious to eyes and skin.	Translocated through roots; pre-emergence weed killer.
16	Sodium TCA [sodium trichloroacetate]		MW=181.4; MP=d. ; purity=90% minimum.	v. s. w.; i. oil.	5000 rat; 3640 mouse; 4280 chick.	Concentrate injurious to eyes; irritating to skin.	Translocated through roots; pre-emergence.
17	CIPC [isopropyl N-(3-chlorophenyl)-carbamate]		MW=213.6; MP=41 ; BP= 247 d.; sp gr=1.18 30/20; purity=98-99%.	sl. s. w. (108 ppm); v. s. aromatic solvents	5000-7000 rat; 5000 rabbit.	No hazard to skin. No problem from absorption or sensitization.	Residual pre-emergence; translocated through roots.
18	Monuron [3-(p-chloro-phenyl)-1, 1-dimethyl-urea]		MW=198.6; MP=170; sp gr= 1.25; purity=80%.	sl. s. w. (230 ppm); sl. oil (229 ppm).	3500 rat; 670 g. pig; 1500 rabbit.	None. No problem from absorption or sensitization.	Translocated; sterilant; residual pre-emergence.
19	[Ammonium sulfamate]		MW=114.3; MP=131-132 (tech.); purity=80%.	s. w. (232 g/100 g).	3900 rat.	No hazard to skin from irritation; not a sensitizer.	Translocated; contact sterilant.
20	[Potassium cyanate]	KOCN	MW=81.1; MP=315; sp gr= 2.056; purity=92%.	s. w. (72%); sl. oil; sl. s. bz., al.	780[3] rat; 1050 mouse; 230[3] rabbit.	-	Contact.
21	[Phenylmercuri-trieth-anolammonium lactate]		MW=515; MP=126; purity= 99%.	v. s. w; sl. s. oil; s. al. , gly; glycols.	>0.67 g. pig; >0.10 monkey.	Seriously injurious to eyes; concentrate seriously injurious to skin; readily absorbed through skin.	Contact; translocated through roots.
22	PCP [pentachlorophenol]		MW=266.3; MP=191; BP= 310 d. ; sp gr=1.94 9^{25}; purity=83%.	sl. s. w. (15 ppm); s. xylene, acet.	50-500 rat, g. pig, rabbit; chick.	Injurious to eyes; concentrate injurious to skin; toxic amounts readily absorbed through skin. Poisonous to humans and other warm-blooded animals.	Contact and/or pre-emergence weed killer; translocated through roots.
23	DNBP [4, 6-dinitro-2-sec. -butylphenol]		MW=239.1; MP=39. 3[2] 0. 3; BP=d. ; purity=95%.	i. w. ; s. oil, kerosene; v. s. xylene.	40 rat; 25 g. pig; 26 chick.	Painful, not injurious to eyes; not irritating to skin, but readily absorbed in toxic amounts. Poisonous to humans and other warm-blooded animals.	Contact and/or pre-emergence weed killer.
24	Triethanolamine salt of 4, 6-dinitro-2-sec.-butyl phenol [triethanol-ammonium 4, 6-dinitro-2-sec.-butylphenate]		MW=378.1; sp gr=1.104 ^{20}; purity= 3 lb/gal DNBP	v. s. w., i. oil.	45 rat; 35 g. pig; 28 chick.	Same as DNBP (above).	Contact and/or pre-emergence weed killer.
25	NPA [N-(1-naphthyl)-phthalamic acid]		MW=291 4; MP=175-180; sp gr=1. 35-1. 45; purity= 95% minimum.	sl. s. w. (0. 02%); sl. s. organic solvents.	>8200 (test animal not specified).	No hazard to skin; not absorbed.	Selective systemic pre-emergence weed killer.
26	Dalapon. sodium salt [sodium 2, 2-dichloro-propionate]		MW=164. 9; MP=193-197; purity=68% in formulations.	s. w. (50%); sl. s. oil (0. 25%).	6590-8120 rat; >4000 mouse; 3360 g. pig; 5660 chick.	Irritating and injurious to eyes; concentrate irritating to skin; no problem from absorption.	Systemic post-and pre-emergence weed killer.
27	2-(2, 4, 5-TP) [2-(2, 4, 5-trichlorophenoxy)pro-pionic acid]		MW=268. 4; MP=179-181; purity=95%+.	i. w. , oil.	650 rat; 600-1400 (esters) rat, g. pig, mouse, chick.	Concentrate injurious to eyes; irritating to skin upon prolonged contact.	Systemic weed and woody plants killer.
28	[Ethyl xanthogen disulfide]	$(C_2H_5OCS_2)_2$	MW=242. 4 (calc.); MP= 27-29; BP=112 d. ; sp gr= 1. 26[25]/15. 5; purity=80%.	i. w. ; 100% s. bz. , acet.	603 rat; 504 g. pig; 781 rabbit.	Concentrate irritating and readily absorbed in toxic amounts. It is a sensitizer.	Contact, some pre-emergence.
29	Cyanamid [calcium cyanamide]	Not established. May be CaN-CN or 	MW=80. 1; MP=1300 (subl.); sp gr=2. 34; purity 44-57%.	sl. s. w. ; i. al.	1400 rabbit.	Injurious to eyes; concentrate irritating and injurious to skin on long contact.	Contact; pre-planting sterilant.
30	[Methyl bromide]	CH_3Br	MW=95. 0; MP=-93 (fr. p); BP=3. 5760; sp gr=1. 732 $^{0/0}$.	s. w. (0. 09%); s. bz.	75 g. pig; 50 rabbit.	Injurious to eyes; concentrate injurious to skin on prolonged contact. Poisonous.	Sterilant (seeds).
31	Stoddard solvent		MP=not more than 50% distilled at 177°C; sp gr= 0. 784 $^{16/16}$.	i. w.	2000 rat.	Irritant upon prolonged or repeated exposure.	Contact selective.

/1/ av. =average; BP=boiling point, °C, with superscript, where present, indicating pressure; calc. =calculated; com'l=commercial; d. =decomposes; fr. p. =freezing point; MP=melting point; MW=molecular weight; sp gr =specific gravity (or density), with superscript indicating temperature of measurement (for liquids, sp gr of the solution is referred to that of water at the same temperature, unless otherwise indicated); subl. =sublimes, tech. =technical. /2/ acet. =acetone; al. =ethyl alcohol (95%); arom. =aromatic; bz. =benzene; gly. =glycerol; i. =insoluble; ppm=parts per million; s. =soluble; sl. =slightly sol. =solution; solv. =solvent(s); v. =very; w. =water. /3/ g. pig=guinea pig. /4/ sol. =solution. /5/ Refers to 4 lb acid equivalent aqueous formulation.

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2, 4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2, 4-D is not feasible. Species resistant to 2, 4-D are listed in Fn 1 appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

	Species[1]	Response
	Annual and Winter Annual Weeds	
1	Bassia, five-hooked (Bassia hyssopifolia)	I
2	Bedstraw (Galium spp)	I
3	Beeplant, Rocky Mountain (Cleome serrulata)	S
4	Beet, wild (Beta maritima)	I
5	Beggar-tick (Bidens frondosa)	I
6	Bitterweed (Helenium tenuifolium)	S
7	Buckwheat, wild (Polygonum convolvulus)	I, R
8	Bur, blue [stickseed] (Lappula echinata)	S
9	Bush, burning [annual kochia] (Kochia scoparia)	S
10	Buttercup, field (Ranunculus arvensis)	S
11	Butterfly weed (Gaura parviflora)	S
12	Buttons, Australian brass (Cotula australis)	S
13	Carelessweed (Amaranthus palmeri)	S
14	Carpetweed (Mollugo verticillata)	I, R
15	Cheeseweed (Malva parviflora)	S
16	Chickweed, common (Stellaria media)	S, I
17	Cinquefoil, rough (Potentilla monspeliensis)	S
18	Clover, bur (Medicago hispida)	S
19	Clover, sour (Melilotus indica)	I
20	Cocklebur (Xanthium spp)	S
21	Cockle, purple [corncockle] (Agrostemma githago)	I, R
22	Coreopsis (Coreopsis tinctoria)	I
23	Corn flower (Centaurea cyanus)	I
24	Cucumber, wild (Sicyos angulatus)	S
25	Dodders (Cuscuta spp)	I
26	Elder, marsh (Iva xanthifolia)	S
27	Fanweed [Frenchweed, stinkweed, pennycress] (Thlaspi arvense)	S
28	Fiddleneck (Amsinkia spp)	I
29	Filarea, red stem [storksbill] (Erodium cicutarium)	I
30	Filarea, white stem [storksbill] (E. moschatum)	I
31	Flax, false (Camelina spp)	S
32	Fleabane, Canada (Erigeron canadensis)	I
33	Fleabane, daisy and others (E. annuus, Erigeron spp)	I
34	Flower-of-an-hour [bladder Ketmia] (Hibiscus trionum)	S
35	Foxtail, yellow (Setaria glauca)	I, R
36	Galinsoga (Galinsoga parviflora)	S
37	Goatsbeard (Tragopogon spp)	S
38	Goosefoot, narrow-leaved (Chenopodium leptophyllum)	S
39	Goosefoot, nettleleaf (C. murale)	S
40	Goosefoot, oak-leaved (C. glaucum)	I
41	Gromwell, corn (Lithospermum arvense)	I
42	Groundcherry (Physalis spp)	S
43	Halogeton (Halogeton glomeratus)	S
44	Hemp (Cannabis sativa)	I
45	Henbit [dead-nettle] (Lamium amplexicaule)	I
46	Indigo [coffee-weed] (Sesbania macrocarpa)	S
47	Indigo, curly (Aeschynomene virginia)	I
48	Jewelweed (Impatiens pallida)	S
49	Jimson weed (Datura stramonium)	S
50	Knotweed, common [doorweed] (Polygonum aviculare, P. erectum)	I, R
51	Knotweed, silver-sheathed (P. argyrocoleon)	I, R
52	Lamb's quarter (Chenopodium album)	S, I
53	Lettuce, prickly (Lactuca scariola)	S, I
54	Lettuce, wild (Lactuca spp)	I
55	Mallow (Malva neglecta)	I
56	Mallow, bull (M. borealis)	S
57	Mallow, Indian [velvetleaf, butterprint] (Abutilon theophrasti)	S
58	Mallow, roundleaved or common (Malva rotundifolia)	S, I
59	Mare's-tail [Canada fleabane] (Erigeron canadensis)	I
60	Mayweed [dog fennel] (Anthemis cotula)	I
61	Medic, black [yellow trefoil] (Medicago lupulina)	S
62	Mexican weed (Caperonia castaneaefolia)	S
63	Morning-glory, annual (Ipomoea spp)	S
64	Mullein, turkey (Eremocarpus setigerus)	S
65	Mustard, ball (Neslia paniculata)	S
	Annual and Winter Annual Weeds (concluded)	
66	Mustard, blue (Chorispora tenella)	S
67	Mustard, hares-ear (Conringia orientalis)	S
68	Mustard, tansy (Descurainia pinnata)	S
69	Mustard, tumbling (Sisymbrium altissimum)	S
70	Mustard, field [charlock] (Brassica arvensis)	S
71	Mustard, wild (B. kaber)	S
72	Mustard, wormseed (Erysimum cheiranthoides)	S
73	Nightshade, black (Solanum nigrum)	S, R
74	Nightshade, cut-leaved (S. triflorum)	I
75	Nightshade, hairy (S. virginum)	I
76	Orache [saltbush] (Atriplex hastata)	S
77	Ox-tongue, bristly (Picris echioides)	S
78	Peppergrass (Lepidium spp)	S
79	Pigweed, prostrate (Amaranthus blitoides)	I
80	Pigweed, rough (A. retroflexus)	S, I
81	Pigweed, tumbling (A. graecizans)	S, I
82	Pimpernel (Anagallis arvensis)	I
83	Pineapple weed [wild marigold] (Matricaria matricarioides)	S
84	Poppy, Roemeria (Roemeria refracta)	S
85	Poppy, white prickly (Argemone intermedia)	I
86	Primrose, cut-leaved (Oenothera laciniata)	S
87	Puncture vine [goat-head, bull-head, galtrop] (Tribulus terrestris)	S
88	Purslane (Portulaca oleracea)	I, R
89	Radish, wild (Raphanus rhaphanistrum)	S
90	Ragweed, common (Ambrosia artemisiifolia)	S, I, R
91	Ragweed, giant (A. trifida)	S
92	Rape, annual (Brassica napus)	S
93	Rape, bird's [common yellow mustard] (Brassica campestris)	S
94	Redweed (Melochia corchorifolia)	S
95	Rocket, London (Sisymbrium irio)	S
96	Rocket, yellow (Barbarea vulgaris)	S
97	Saltbush (Atriplex spp)	S
98	Shepherd's purse (Capsella bursa-pastoris)	S, I
99	Smartweed [lady's thumb and others] (Polygonum persicaria)	I, R
100	Speedwells (Veronica spp)	I
101	Spikeweed, common (Centromadia pungens)	I
102	Spurge, mat (Euphorbia glyptosperma)	I
103	Spurge, spotted (E. maculata)	I, R
104	Sunflower, wild (Helianthus annuus)	S
105	Telegraph plant (Heterotheca grandiflora)	I
106	Thistle, blessed (Cnicus benedictus)	I
107	Thistle, distaff (Carthamus lanatus)	I
108	Thistle, milk (Silybum marianum)	S
109	Thistle, Russian (Salsola kali)	S, I
110	Thistle, sow[common, annual] (Sonchus oleraceus)	S
111	Thistle, sow [spiny or prickly] (S. asper)	S, I
112	Thistle, yellow star (Centaurea solstitialis)	S
113	Tocalote (C. melitensis)	I
114	Vervain (Verbena bracteosa)	S
115	Vetches, wild (Vicia spp)	S
116	Wintercress, bitter (Barbarea vulgaris)	S
117	Wormwood (Artemisia spp)	S
	Herbaceous Biennial and Perennial Weeds	
118	Agroseris (Agroseris spp)	S
119	Alfalfa (Medicago spp)	S
120	Alligator weed (Alternanthera piloxeroides)	I
121	Arrowhead [arrow weed] (Sagittaria spp)	I
122	Artichoke, Jerusalem (Helianthus tuberosus)	S
123	Aster (Aster spp)	I
124	Aster, woody (Xylorrhiza parryi)	S
125	Avens, three-flowered (Geum triflorum)	I
126	Bedstraws, northern (Galium boreale)	I, R
127	Bindweed, field [small flowered morning-glory] (Convolvulus arvensis)	S, I
128	Bindweed, hedge [large flowered morning-glory] (C. sepium)	S
129	Biscuit root (Lomatium leptocarpum)	S

340. RESPONSE TO 2, 4-D: VARIOUS WEEDS AND UNDESIRABLE WOODY PLANTS (Continued)

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2, 4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2, 4-D is not feasible. Species resistant to 2, 4-D are listed in Fn 1 appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

	Species[1]	Response
	Herbaceous Biennial and Perennial Weeds (continued)	
130	Blueweed (Echium vulgare)	I
131	Blueweed (Helianthus ciliaris)	I
132	Bouncing Bet (Saponaria officinalis)	I
133	Buckwheat, false (Polygonum scandens)	I
134	Burdock (Arctium minus)	S
135	Burnet (Sanguisorba minor)	S
136	Buttercup, tall and others (Ranunculus acris, R. spp)	I
137	Camas, death (Zygadenus gramineus)	S
138	Carrot, false (Pseudocymopteris montanus)	S
139	Carrot, wild (Daucus carota)	S
140	Catnip (Nepeta cataria)	S
141	Cattail (Typha spp. esp. T. latifolia)	I
142	Chickweed, field (Cerastium arvense)	S, I
143	Chickweed, mouse-ear (C. vulgatum)	S, I, R
144	Chicory (Cichorium intybus)	S
145	Cinquefoil [fivefingers] (Potentilla fillipes, P. glaucophylla)	S
146	Cinquefoil, silvery (P. argetea)	I
147	Comfrey (Symphytum officinale)	I
148	Coneflowers (Rathbida spp)	S
149	Cress, Austrian field (Roripa austriaca)	S
150	Cress, hoary [whitetop, whiteweed] (Lepidium drabs, Cardaria drabs)	S, I, R
151	Cress, western yellow (Radicula sylvestris)	I
152	Daisy, ox-eye (Chrysanthemum leucanthemum)	I, R
153	Dandelions (Taraxacum spp, esp. T. officinale)	S
154	Dandelion, fall (Leontodon autumnale)	S
155	Dock, curled and others (Rumex crispus, R. spp)	I
156	Dogbane (Apocynum cannabinum)	S, I
157	Dragonhead (Dracocephalum parviflorum)	S
158	Fleabane (Erigeron spp)	S
159	Fiddleneck (Amsinkia spp)	S
160	Figwort (Scrophularia lanceolata)	S
161	Four-o'clock (Mirabilis jalapa)	S
162	Garlic, wild (Allium vineale, Allium spp)	S, I
163	Gaura (Gaura spp)	S
164	Geranium [cranesbill] (Geranium carolinianum)	I
165	Goatsbeard (Tragopogon spp)	S, I
166	Goatsrue (Galega officinalis)	S
167	Goldaster, hairy (Chrysopsis villosa)	S
168	Goldenrods (Solidago spp)	S, I
169	Gourd, wild (Cucurbita foetidissima)	I
170	Groundcherry, perennial (Physalis spp)	I, R
171	Gumweed (Grindelia squarrosa, G. perennis)	S
172	Hawkweed, orange (Hieracium aurantiacum)	S, I
173	Heal-all (Prunella vulgaria)	S
174	Hemlock, poison (Conium maculatum)	S
175	Hemlock, water (Cicuta spp)	S
176	Horsetail (Equisetum spp)	S, I
177	Hound's-tongue (Cynoglossum officinale)	I
178	Hyacinth, water (Eichhornia crassipes)	S
179	Iron weed (Vernonia baldwinii)	I
180	Ivy, ground [creeping Charlie] (Glecomahederacea, Nepeta hederacea)	S, I
181	King devil [yellow-flowered hawkweed] (Hieracium spp)	I
182	Knapweeds [esp. Russian knapweed] (Centaurea spp, C. picris)	S, I, R
183	Larkspur, low (Delphinium geyeri)	S, I, R
184	Larkspur, Menzesia (D. menzesi)	S
185	Larkspur, tall (D. barbeyi)	S
186	Lettuce, blue (Lactuca pulchella)	S, I
187	Licorice, wild (Glycorrhiza lepidota)	S
188	Locoweed (Oxytropis lamberti)	S
189	Loosestrife, purple (Lythrum salicaria)	I
190	Lupine, mountain (Lupinus alpestris)	S
191	Lupine, silvery (L. argenius)	S
192	Mallow, poppy (Callirhoe involucrata)	S
193	Mallow, round-leaved or common (Malva neglecta)	S, I
194	Milkweed, purple-flowered (Asclepsas purpures)	I
195	Milkweed, woolly-pod (A. eriocarpa)	S

	Species[1]	Response
	Herbaceous Biennial and Perennial Weeds (concluded)	
196	Milkweed, whorled (Asclepias verticillata)	S, R
197	Moonseed (Menispermum canadense)	S
198	Mule's ear (Wyethia amplexicaule)	S
199	Mullein, common [Mullen] (Verbascum thapsus)	S, R
200	Nettle, hedge (Stachys palustris)	S
201	Nettle, stinging (Urtica dioica)	S
202	Nettle, stinging (U. gracilis)	I
203	Nettle, white horse (Solanum eleagnifolium)	S, R
204	Nutgrass, northern (Cyperus esculentus)	I
205	Nutgrass, southern (C. rotundus)	I
206	Onion, wild (Allium canadense)	I
207	Onion, wild (A. acuminatum)	S
208	Paranip, wild (Pastinaca sativa)	S
209	Pentstemon, Rydberg (Pentstemon rydbergii)	S
210	Pennywort, lawn (Hydrocotyle rotundifolia)	S
211	Pignut, Indian (Hoffmannseggia densiflora)	S
212	Plantains, common (Plantago major)	S
213	Plantains (English) [buckhorn] (P. lanceolata)	S
214	Pokeweed (Phytolacca americana)	I
215	Potato, wild sweet [man-of-the-earth] (Ipomoea pandurata)	S, I
216	Poverty weed (Iva axillaris)	S, I, R
217	Poverty weed, silver-leaved [white franseria] (Franseria discohor)	S
218	Primrose, evening (Oenothera spp)	S
219	Puccoon, hoary (Lithospermum canescens)	I
220	Ragweed, bur [Woolly-leaved poverty weed] (Franseria tomentosa)	I
221	Ragweed, false (Iva ciliata)	S
222	Ragweed, western (perennial) [Ambrosia psilostachys)	S
223	Ragwort, tansy (Senecio jacobaea)	I, R
224	Rocket, yellow (Barbarea vulgaris)	I
225	Rosin weed (Silphium spp)	S
226	Rush, slender (Juncus tenuis)	S
227	Sage, pasture (Artemisia frigida)	S, I, R
228	Sage, sand (A. gnaphaloides)	S
229	St. John's-wort [klamath weed, goatweed] (Hypericum perforatum)	S, R
230	Skeleton weed (Lygodesmia juncea)	I
231	Smartweed, swamp [tanweed] (Polygonum coccineum, P. muhlenbergia)	I, R
232	Sneezeweed, orange (Helenuun hoopesii)	S, I
233	Sorrel, sheep (Rumex acetosella)	I, R
234	Spurges, leafy (Euphorbia esula)	I, R
235	Stonecrop (Sedum acre)	S
236	Sunflower, false (Heliopsis scabra)	S
237	Sunflower, perennial (Helianthus spp, H. maximiliani, H. grosseserratus)	S
238	Sweetclover (Melilotus spp)	S
239	Teasel (Dipsacus sylvestris)	I
240	Thistle, artichoke [cardoon] (Cynara cardunculus)	S
241	Thistle, biennial (Cirsium spp)	S
242	Thistle, bull (Cirsium lanceolatum)	S, I
243	Thistle, bull (C. vulgare)	I
244	Thistle, Canada (C. arvense)	I
245	Thistle, perennial sow (Sonchus arvensis)	S, I
246	Tule (Scirpus acutus)	I
247	Vervains (Verbena spp)	S, I, R
248	Vetch, two-grooved (Astragalus bisulcatus)	S
249	Vetch, narrow-leaved (A. bigiensis)	S
250	Vetch, crown (Coronilla varia)	S
251	Vetch, wild (Vicia spp)	S
252	Wormwood, biennial (Artemisia biennia)	S, I
253	Yarrow, common (Achillea millifolium)	I, R
254	Yarrow, western (A. lanulosa)	S
	Woody Plants	
255	Alder (Alnus spp)	S
256	Apple, American crab (Pyrus coronaria)	S
257	Aspen (Populus spp, esp. P. tremuloides)	S
258	Barberry, common and others (Berberis vulgaris, Berberis spp)	I, R

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2, 4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations. (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2, 4-D is not feasible. Species resistant to 2, 4-D are listed in Pn ! appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

	Species[1]	Response		Species[1]	Response
	Woody Plants (continued)			Woody Plants (concluded)	
259	Barberry, native [Colorado] (Berberis fendleri)	S	302	Hazel (Corylus spp)	S
260	Basswood (Tilia americana)	I, R	303	Hickory (Carya spp)	S, I, R
261	Birch (Betula spp)	S	304	Honeysuckle (Lonicera japonica)	S
262	Blackberry, common (Rubus spp)	I, R	305	Honeysuckle, bush (Diervilla lonicera)	S
263	Blueberry (Vaccinium spp)	S	306	Hornbeam (Ostrya virginiana)	S
264	Brier, common, green (Smilax rotundifolia)	I	307	Ivy, poison (Rhus radicans, R. toxicodendron)	S, I
265	Broom, Scotch (Cytisus spp)	I	308	Juneberry (Amelanchier alnifolia)	S
266	Buckbrush [coralberry, Indian currant] (Symphoricarpos orbiculatus)	I	309	Lambkill [laurel, sheep] (Kalmia angustifolia)	S, R
267	Buckbrush, western [western snowberry, wolfberry] (S. occidentalis)	S	310	Lead plant (Amorpha canescens)	S
268	Burrowweed (Haplopappus tenuisectus)	I	311	Lilac (Syringa vulgaris)	R
269	Cactus, cholla (Opuntia imbricata)	I	312	Locust, black (Robinia pseudoacacia)	S
270	Ceanothus, wedgeleaf (Ceanothus cuneatus)	I	313	Lotebush (Condalia obtusifolia)	S, I
271	Cedar, salt (Tamarix gallica)	S	314	Maple (Acer spp)	I, R
272	Cherry, wild [black and red] (Prunus spp)	S	315	Maple, Manitoba (A. negundo)	S
273	Chestnut (Castanea dentata)	I	316	Mesquite, honey (Prosopis juliflora var. glandulosa)	S, I
274	Chokecherry (Prunus virginiana)	S	317	Mulberry (Morus spp)	I
275	Cottonwood (Populus spp)	S	318	Myrtle, wax (Myrica cerifera)	S
276	Creeper, Virginia (Parthenocissus quinquifolia)	S	319	Oak, black jack (Quercus marilandica)	S, I
277	Currant, Alpine (Ribes montigenum)	I, R	320	Oak, post (Q. stellata)	I
278	Currant, American black (R. americanum)	S	321	Oak, laurel (Q. imbricaria)	I
279	Currant, Hudson Bay (R. hudsonianum)	S	322	Oak, white (Q. alba)	I
280	Currant, prickly (R. lacustre)	I, R	323	Oak, scrub (Q. illicifolia)	I
281	Currant, red-flowered (R. sanguineum)	S	324	Plum, wild (Prunus spp)	S, I
282	Currant, red swamp (R. triste)	S	325	Poplar, balsam (Populus balsamifera)	I
283	Currant, Sierra Nevada (R. nevadense)	S	326	Prickly-ash, northern (Xanthoxylum americanum)	I
284	Currant, squaw (R. cereum)	S	327	Rose, Cherokee (Rosa laevigata)	S
285	Currant, stink (R. bracteosum)	S	328	Sage, black (Salvia mellifera)	I
286	Currant, western black (R. petiolare)	S	329	Sage, purple (S. leucophylla)	I
287	Dewberry (R. vilosus)	I	330	Sage, white (S. apiana)	I
288	Dogwood (Cornus spp)	S	331	Sagebrush, big (Artemisia tridentata)	S, I
289	Elderberry (Sambucus canadensis, Sambucus spp)	S	332	Sagebrush, black (A. nova)	S
290	Elder, box (Acer negundo)		333	Sagebrush, California or coastal (A. californica)	S
291	Elm (Ulmus spp)	S, I	334	Saltbush (Atriplex spp)	S
292	Fern, sweet (Myrica saplenifolia, Comptonia perigrina)	S, R	335	Sassafras (Sassafras albidum)	S
293	Gooseberries, gummy (Ribes lobii)	S	336	Silverberry (Elaeagnus commutata)	S, I
294	Gooseberries, Sierra (R. roezlii)	S	337	Spicebush (Benzoin aestivale)	S
295	Gooseberries, Siskiyou (R. binominatum)	S	338	Sumac, poison, staghorn and others (Rhus spp)	S
296	Gooseberries, white-stemmed (R. inerme)	S, I	339	Sycamore (Plantanus occidentalis)	S
297	Grape, wild and cultivated (Vitis spp)	S	340	Tamarisk (Tamarix spp)	I
298	Gum, sweet (Liquidambar styraciflua)	S, I	341	Tobacco, tree (Nicotiana glauca)	S
299	Gum, tupelo or black (Nyssa sylvatica)	S	342	Tree-of-heaven (Ailanthus glandulosa)	S, I
300	Hardhack (Spiraea spp)	I	343	Viburnum (Viburnum spp)	I
301	Hawthorn [thornapple] (Crataegus spp)	S, R	344	Walnut, black (Juglans nigra)	I
			345	Walnut, white (J. cinerea)	S
			346	Willow, species highly varisible (Salix spp)	S, I

/1/ Resistant species. Annual and winter annual weeds: Buckwheat, tartary (Fagopyrum tataricum); bur, buffalo (Solanum rostratum); catchfly, night-flowering and others (Silene noctiflora, Silene spp); chess (Bromus secalinus); crabgrass (Digitaria sanguinalis); foxtail, green (Setaria viridis); grasses, all weedy annual species; hemp-nettle (Galeopsis tetrahit); oats, wild (Avena fatua); sorrel, wood (Oxalis spp); spurrey, corn (Spergula arvensis). Herbaceous biennial and perennial weeds: beardtongue (Penstemon laevigatus); bittersweet [climbing nightshade] (Solanum dulcamara); bracken (Pteris aquilina, Pteridium aquilinum); cactus, prickly pear (Opuntia spp); campion, bladder (Silene latifolia, S. cucubalus); catchfly, night-blooming (S. noctiflora); cinquefoil, shrubby (Potentilla fruticosa); cockle, white (Lychnis alba); dandelion, timber (Danthonia intermedia); dog-bane, spreading (Apocynum androsaemifolium); ferns, many kinds; goutweed (Aegopodium podograria); grasses, all species; harebell [bellflower] (Campanula spp); knotweed [smartweed] (Polygonum spp); larkspur, tall (Delphinium occidentale); mallow, alkali [white malva] (Sida hederacea); milkweed, climbing (Gonolobus laevis, G. gonocarpus); milkweed (Asclepias spp, A. asniaca); milkweed, showy (A. speciosa); nettle, horse (Solanum carolinense); quackgrass (twitch grass] (Agropyron repens); sedges (Carex spp); sorrel, wood or red ox (Oxalis spp); spurges, cypress (Euphorbia cyparissias); spurges, snow-on-the-mountain (E. marginata); strawberry, wild (Fragaria spp); tansy (Tanacetum vulgare); tick-trefoil (Desmodium spp); tosdflax (Linaria vulgaris); whitetop, globe-podded (Cardaria pubescens). Woody plants: apple, common (Pyrus malus); aborvitae [white cedar] (Thuja occidentalis); ash, green (Fraxinus pennsylvanica); ash, white (F. americana); beech (Fagus spp); buckthorn, common or European (Rhamnus cathartica); cedar, dryland (Juniperus punchota); cedar, red (J. virginiana); chokeberry (Aronia melanocarpa), elm, red (Ulmus fulva); hackberry (Celtis occidentalis); hemlock (Tauga spp); locust, honey (Gleditsia triacanthos); mahonia (Mahonia repens); meadowsweet (Spiraea latifolia), mesquite, velvet (Prosopis juliflora var. velutina); orange, osage [hedge, bedgeapple] (Maclura pomifera); pines (Pinus spp); rabbitbrush, small (Chrysothamnus stenophyllus); raspberry, wild [black and red] (Rubus spp); rhododendron (Rhododendron canadense); rose, wild [species variable, mostly resistant] (Rosa spp); spruces (Picea spp).

341. GROWTH REGULATORS PROMOTING CELL ELONGATION, RELATIVE ACTIVITY. PLANTS

The elongation effect is determined by floating 15 apical sections (3mm in length) of decapitated Avena coleoptiles, 90-92 hours old, on the surface of 25 ml of solution in a covered Petri dish at 24°C for 24 hours. Where concentrations greater than 10^{-2}M are required for an elongation of 0.15 mm, the pH of the solutions is adjusted to 5.6 with NaOH.

$$\text{Activity Index} = \frac{\text{molar concentration of indole-3-acetic acid inducing an elongation of 0.15mm x 100}}{\text{molar concentration of growth regulator inducing an elongation of 0.15 mm}}$$

	Compound	Activity Index
1	Indole-3-acetic acid ($5 x 10^{-8}$M)	100
2	Indole-3-acetonitrile	250
3	4-Chloroindole-3-acetic acid	140
4	2-Methylindole-3-acetic acid	1.5
5	4,7-Dichloro-2-methylindole-3-acetic acid	0.1
6	5,7-Dichloro-2-methylindole-3-acetic acid	1.5
7	Indole-3-butyric acid	15
8	Indole-3-propionic acid	1.5
9	Phenoxyacetic acid	0.03
10	o-Bromophenoxyacetic acid	0.1
11	m-Bromophenoxyacetic acid	2.5
12	p-Bromophenoxyacetic acid	1.5
13	2,4-Dibromophenoxyacetic acid	12.5
14	2,6-Dibromophenoxyacetic acid	Inactive
15	2,4,6-Tribromophenoxyacetic acid	Inactive
16	o-Chlorophenoxyacetic acid	0.06
17	m-Chlorophenoxyacetic acid	2
18	p-Chlorophenoxyacetic acid	5
19	2,4-Dichlorophenoxyacetic acid	25
20	2,6-Dichlorophenoxyacetic acid	Inactive
21	3,5-Dichlorophenoxyacetic acid	Inactive
22	2,4,5-Trichlorophenoxyacetic acid	25
23	2,4,6-Trichlorophenoxyacetic acid	Inactive
24	2,4-Dichloro-6-methylphenoxy-acetic acid	2
25	2,4-Dichloro-5-nitrophenoxy-acetic acid	0.2
26	2-Ethyl-4-chlorophenoxyacetic acid	Inactive
27	p-Fluorophenoxyacetic acid	6
28	m-Trifluomethylphenoxyacetic acid	7
29	o-Iodophenoxyacetic acid	0.1
30	p-Iodophenoxyacetic acid	Inactive
31	2,4-Diiodophenoxyacetic acid	Inactive
32	o-Methoxyphenoxyacetic acid	Inactive
33	m-Methoxyphenoxyacetic acid	0.1
34	p-Methoxyphenoxyacetic acid	0.03
35	o-Methylphenoxyacetic acid	0.2
36	m-Methylphenoxyacetic acid	0.07
37	p-Methylphenoxyacetic acid	0.05
38	2,4-Dimethylphenoxyacetic acid	0.5
39	2,5-Dimethylphenoxyacetic acid	0.2
40	3,5-Dimethylphenoxyacetic acid	Inactive
41	2,4,6-Trimethylphenoxyacetic acid	Inactive
42	o-Nitrophenoxyacetic acid	Inactive
43	m-Nitrophenoxyacetic acid	0.2
44	p-Nitrophenoxyacetic acid	0.1
45	2,4-Dinitrophenoxyacetic acid	Inactive
46	Phenylacetic acid	1
47	α-Aminophenylacetic acid	Inactive
48	p-Aminophenylacetic acid	0.05
49	m-Fluophenylacetic acid	1.5
50	p-Fluophenylacetic acid	1.5
51	2,5-Dihydroxyphenylacetic acid	0.02
52	p-Iodophenylacetic acid	Inactive
53	2,4-Dimethylphenylacetic acid	0.5
54	3,5-Dimethylphenylacetic acid	0.5
55	2,4,6-Trimethylphenylacetic acid	Inactive
56	p-Nitrophenylacetic acid	Inactive
57	p-Phenylphenylacetic acid	Inactive
58	Diphenylacetic acid	Inactive
59	Benzoic acid	Inactive
60	o-Aminobenzoic acid	Inactive
61	o-Bromobenzoic acid	0.1
62	m-Bromobenzoic acid	Inactive
63	p-Bromobenzoic acid	Inactive
64	o-Chlorobenzoic acid	0.05
65	m-Chlorobenzoic acid	Inactive
66	p-Chlorobenzoic acid	Inactive
67	2,4-Dichlorobenzoic acid	Inactive
68	2,5-Dichlorobenzoic acid	1
69	o-Fluobenzoic acid	Inactive
70	Pentachlorobenzoic acid	Inactive
71	o-Iodobenzoic acid	Inactive
72	2-Amino-3,5-diiodobenzoic acid	Inactive
73	2,3,5-Triiodobenzoic acid	50
74	3,4,5-Triiodobenzoic acid	Inactive
75	2,6-Dimethylbenzoic acid	0.05
76	2,6-Dimethyl-3-bromobenzoic acid	3
77	2,6-Dimethyl-3-chlorobenzoic acid	2
78	2,6-Dimethyl-3-iodobenzoic acid	2.5
79	2,6-Dimethyl-3-nitrobenzoic acid	0.1
80	o-Nitrobenzoic acid	0.1
81	Benzothiaxyl-2-oxyacetic acid	0.5
82	α-Naphthaleneacetic acid	50
83	β-Naphthoxyacetic acid	0.7
84	2-Phenanthrenecetic acid	Inactive
85	α-Phenoxypropionic acid	0.5
86	Phenylacetonitrile	2
87	α-Naphthaleneacetonitrile	100
88	γ-Phenylbutyric acid	1.5
89	p-Chlorophenylglycine	1
90	β-Phenylpropionic acid	Inactive

342. GROWTH REGULATORS, RELATIVE ACTIVITIES. PLANTS

Data indicate relative activity as tested by various methods. For each compound listed, as the concentration increases, the response occurs from 0 to +1, and then to a -1 when the substance becomes inhibitory. Values are applicable to the maximum positive response.

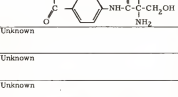
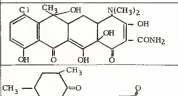
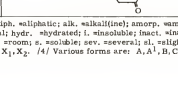
	Compound	Activity Relative to Indoleacetic Acid, %					
		Avena Curvature Test	Pea Curvature Test	Rooting of Cuttings[1]	Tomato Petiole Bending	Bud Inhibition[1]	Inhibition of Root Elongation[2]
1	Indoleacetic acid	100	100	100	100	100	100
2	Indolebutyric acid	8	190	150	6	>100	10
3	Indene-3-acetic acid	1	20	45		14	20
4	α-Naphthalenesecetic acid 	2.5	300	150	50	>100	4
5	β-Naphthoxyacetic acid 	0	200	25	15	100	
6	Phenylacetic acid	0.02	10	0	0.6	0	0.3
7	Phenoxyacetic acid 	0	0	0	Trace		
8	2,4-Dichlorophenoxyacetic acid 	0	800-1200		100		30

/1/ Variability encountered with species. Generally, indolebutyric acid is most effective; naphthaleneacetic and indoleacetic acids are 2nd and 3rd, respectively. /2/ In oat (Avena sativa).

343. GROWTH REGULATORS: APPLICATIONS AND USES

	Principal Use	Chemical	Concentration Range, Treatment
1	Propagation of plants (rooting of cuttings)	Indoleacetic acid; indolebutyric acid.	1-80 mg/L, H_2O, soak cuttings 5-24 hr.
2			1-15 mg/ml of 50-95% alcohol; dip cuttings.
3			1-12 mg/g; talcum powder preparation.
4		α-Naphthalene-acetic acid.	1-50 mg/L H_2O, soak cuttings 5-24 hr.
5			1-5 mg/g; talcum powder preparation.
6		Indolebutyric acid and α-naphthaleneacetic acid mixture.	1-8 mg/g (equal parts); talcum powder preparation.
7			1-40 mg (equal parts)/L H_2O, soak cuttings 5-24 hr.
8		Indolebutyric acid	0.3 g/L, foliage spray.
9	Preharvest drop of fruit	α-Naphthalene-acetic acid.	10-20 ppm; water solution for apple spray.
10		2,4-Dichloro-phenoxyacetic acid (2,4-D)	8-24 ppm; water solution for some varieties of apples and oranges.
11	Fruit set of tomatoes	α-(2-Chloro-phenoxy)-propionic acid.	25-40 ppm; water solution sprayed on flowers and large buds.
12		4-Chlorophen-oxyacetic acid[1].	30-40 ppm; water solution sprayed on flowers and large buds.
13		Naphthaleneacetic acid and derivatives[1,2]	40-60 ppm; water solution sprayed on open flowers and large buds.
14	Inhibition of buds	Methyl ester of α-naphthalene-acetic acid.	Vapor, foliage spray.
15	Selective weed killing	Acids, salts, and esters of 2,4-D.	0.1-1% sprays or 1/8 lb to 3 lb per acre, or water solutions, emulsions, or various formulations depending upon purpose.
16		Acids, salts, and esters of 2,4,5-trichlorophen-oxyacetic acid (2,4,5-T); 2,4,5-trichloro-phenoxypro-pionic acid.	0.1-1% sprays or 1/8 lb to 3 lb per acre, (especially used for woody plants), or water solutions, emulsions, or various formulations depending upon purpose.

/1/ Chemical modifies leaves. /2/ Esters used where vapor is necessary.

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color[1]	Melting Point[1] °C
1	Actinomycin(s)[3] A	Streptomyces antibioticus, S. chrysomallus	Weakly basic chromopeptides, quinonoid	$C_{41}H_{58}N_8O_{11}$	Unknown	Red-vermilion platelets	250, 252 d.
	C			$C_{62}H_{89}N_{11}O_{17}$ or $C_{60}H_{83}N_{11}O_{16}$ (?)		Hexagonal bipyr-amids, prisms or needles	C_1:241-243 d, C_2:237-239 d, C_3:232-235 d.
2	Amicetin	Streptomyces vinaceus-drappus; S. fasciculatis	Amphoteric	$C_{29}H_{44}N_8O_9$	Partial 	Hydr.: fine needles; anhy.: tan to colorless powder	Hydr.: 165-169; anhy.: 244-245; HCl:190-192
3	Amimycin (P.A. 105)	Streptomyces antibioticus	Basic	$C_{37}H_{67}NO_{13}$·HCl	Unknown	White crystals	Dihydr.:134-135; HCl:125-128
4	Amphotericin B (Fungizone)	Streptomyces spp	Amphoteric conjugated polyene	Unknown	Unknown	Clusters of long, deep yellow needles	170 d.
5	Antsomycin (Fungicidin)	Streptomyces griseolus	Basic	$C_{14}H_{19}NO_4$	Unknown	Long white needles	140-141
6	Aureothrixin	Streptomyces cellulosflavus n. spp		$C_9H_{10}N_2O_2S_2$		Golden-yellow needles	256-257 d.
7	Azaserine (O-diazoacetyl-L-serine)	Streptomyces fragilis	Amphoteric	$C_5H_7N_3O_4$	$N_2CH\text{-}C\text{-}O\text{-}CH_2\text{-}CH\text{-}COOH$ (O; NH_2)	Light yellow-green needles	146-162 d. before melting
8	Bacitracin(s)[4] (Ayfivin)	Bacillus subtilis	Polypeptides	$C_{65}H_{103}N_{17}O_{16}S$ (proposed)	Uncertain	White amorp. powder	
9	Carbomycin[5] (Magnamycin)	Streptomyces halstedii	Monobasic	C_{41}-$_{42}H_{67}$-$_{69}NO_{16}$	Unknown	White needles or rect. plates	210-218 d.
10	Celesticetin	Streptomyces caelestis	Amphoteric	$C_{24}H_{38}N_2O_9S$	Unknown	Base: white glass	Salicylate: 139
11	Cephalosporin N (Synnematin B, Salmotin)	Cephalosporium sp	A hydrophilic penicillin	$C_{14}H_{21}N_3O_8S$	$(CH_3)_2\text{-}C\text{=}CHCOOH$; NH_2; $NH\text{-}CO\text{-}(CH_2)_2\text{-}CH_2\text{-}CH$ (COOH)	Ba salt: white powder	
12	Chloramphenicol (Chloromycetin)	Streptomyces venezuelae, S. omiyoensis	Neutral	$C_{11}H_{12}N_2O_5Cl_2$	O_2N; $C\text{-}CH_2OH$; $NHCOCHCl_2$	Colorless plates or fine needles	149.7-150.7 corr.
13	Chlortetracycline (Aureomycin)	Streptomyces aureofaciens	Amphoteric	$C_{22}H_{23}N_2O_8Cl$		Base: acicular to bladed; HCl: rhomboid, lemon-yellow	Base: 168-169 HCl: d, above 210
14	Cycloheximide (Actidione)	Streptomyces griseus	Weakly acidic	$C_{15}H_{23}NO_4$		Colorless plates	119-121

/1/ a. =acid; abs. =absolute; ac. =acetic; acet. =acetone; al. =alcohol; aliph. =aliphatic; alk. =alkali[line]; amorp. =amorphous; anhy. =anhydrous; aq. = dilute; eth. =ether; filt. =filtrate; glac. =glacial; h. =hot; hex. =hexagonal; hydr. =hydrated; i. =insoluble; inact. =inactivated; lab. =labile; me.al. = prop. =propylene; pwd. =powder; pyr. =pyridine; rect. =rectangular; rm. =room; s. =soluble; sev. =several; sl. =slight; sol. =solution; solv. =solvent; were made. /3/ Other forms are: actinomycin B, C_1, C_2, C_3, D, Io, I_1, X_1, X_2. /4/ Various forms are: A, A^1, B, C, D, E, F_1, F_2, F_3, G. /5/ Carbo-

Optical Activity[1,2] $[\alpha]_D^{25}$	Solubility[1]	Absorption Maxima,[1] UV, $m\mu$	Stability[1]	Some Other Reactions [1]	
-320 in al.	s. chl., bz., al., acet., 10% HCl; sl. s. w., eth., i. pet. eth., di-i-propyl-o-i, dil. alk.	230-250, 450	Thermostable except in alk. and strong acid.	Transient purple color with conc. NaOH; neg. color with sl. $FeCl_3$; reduced by $Na_2S_2O_4$. H_2 over PtO to pale yellow, reversed by exposure to air.	
C1: -349[20] s. bz., chl., acet.; less s. al., glac. ac. s.				Neg. ninhydrin; gray-brown ppt. with Nessler's; yellow-green fluorescence in me. al. or glac. ac. s.	1
+116.5[24] in 0.1 N HCl	s. n-butanol saturated with w., dil. a., alk.; almost i.w., most org. solv.	305 in w. at pH 6.75; 316 in 0.1 N HCl; 322 in 0.1 N NaOH	Stable as dry solid and pH 3-5; unstable at pH >8.	Neg. Brauton-Marshall and ninhydrin until after hydrolysis; forms sl.s. helianthate and picrate salts.	2
-54 in me. al.	Phosphate s.w.; s. methyl ethyl ketone.	286-289 (broad, low intensity maxima)	0.1% aq. sol. st. at least 24 hr pH 2.2-9.	(?)	3
+410[24] at pH 5 in dimethylformamide	s. glac. ac. s.; i.w., al., acet.	225, 263, 273, 283, 345, 362, 382, 405	st. in solid form room temp.; unstable in sol.	Green color with conc. H_2SO_4; neg. $FeCl_3$, ninhydrin, biuret, Tollen's, Fehling's; absorbs Br_2 in glac. ac. s.	4
-30[-3] in me. al.	s. dil. a., al., me.al., acet.; less s.w.; i.eth., CCl_4.	224, 277, 283, 3.34 mg in 25 ml me. al.	st. rm.temp., thermolab. acid pH.	Infrared: 3545, 3450, 3320, 2890, 2800, 1725, 1610, 1582, 1515, 1470 ..... to 962 (recip. cm).	5
Inactive	sl. s. org. solv.; more s. chl.; i.w.	248, 312(?), 388	Very thermo- and acid stable.	Similar to thiolutin; acid hydrolysis yields an amine, $C_4H_6N_2OS_2$, identical with one so obtained from thiolutin.	6
+9.7[28] in 2N HCl	s.w., h. sq. me. al., al., acet.; sl. s. abs.me.al., al., acet.	250.5 at pH 7	Acidification at pH 2 results in vigorous evolution of N_2 and loss of biological activity.	Pronounced infrared peak at 4.66μ. Neutral solutions are stable.	7
+5[23]±2.5 in 0.02N HCl	s.al., me.al., w.,sl.s.acet., pyr., i.eth., chl., pet.eth.	A, B, D, E: 253; C, G: 250, 268; F_1, F_2, F3: 253, 288	Fairly thermost., esp. at pH 4-5.	Pptd. by heavy metal salts, tannic a.; conc. NaCl; pos. ninhydrin; neg. $FeCl_3$, biuret; inact. by Cu.	8
-58.6[25] in chl.	Salts: s.w., most org. solv.; base: i.w., hexane.	238, 327 in abs. al.	st. at room temp. at pH 5-7.	Neg. ninhydrin, $FeCl_3$; pos. Fehling's, Tollen's; decolorizes Br_2; violet color with 40% H_2SO_4.	9
+124.5[4] in 1 N HCl (as lactylate)	s.a., alk.; i.pH 7-10; salts s.w.	230.3 in 0.01 N al. KOH; 283.7 in 0.01 N H_2SO_4	st. pH 5-7 at 24°C; unst. above pH 9.	Pos. $FeCl_3$, Molisch, Ekkert; neg. Benedict's, ninhydrin, iodoform.	10
Ba salt: + 187[20] in w.	i. most org. solv.; Ba salt: s.w.; sl.s. me. al.; i.al.		Unst. rm. temp. below pH 4 and above pH 9; inact. heavy metal ions pH 7.	Inact. by penicillinase; acid hydrolysis eventually forms a penicilamine; penicillin W is very similar in nature.	11
-25.5[25] in ethyl acetate, +19[25] in al.	s.al., me.al., prop.glycol; sl.s.w., chl., alk.; i.a., bz., pet.eth., veg.oils.	278	Thermostable; alk. labile.	Chlorine non-ionic; neg. $FeCl_3$, Molisch, biuret; not hydrolyzed by papain, trypsin; chymotrypsin, pepsin.	12
Base: -274.9[23] in me.al.; HCl: -295.9[23] in me.al.	Base: s. dil.a., alk., pyr.; less s.al., me.al., acet.; bz.; i.eth., pet.eth.; HCl: s.w., me.al.; sl.s.al.	HCl: 226, 264, 365 in 0.1M H_3PO_4	Thermolab. in strong a.; st. at pH 2.5; unst. at pH 7 at 25°C.	Ppts. with picric a., Reinecke's a., ammonium molybdate; UV shifts in acids, alkali; fluoresces in basic sol.	13
-2.8[25] in me. al.	s.w., all org. solv. except saturated hydrocarbons.	287	Thermostable.	Inactivated at room temp. by acetic anhydride, sodium acetate, dil. alkali.	14

aqueous; bz. =benzene; chl. =chloroform; colorl. =colorless; corr. =corrected; cryst. =crystal(line); cult. =culture; d. =decomposes; def. =definite; dil.= methyl alcohol; min. =mineral; MP = melting; MW = molecular weight; neg. =negative; org. =organic; pet. =petroleum; pos. =positive; ppt. =precipitate; st.=stable; unst.=unstable; veg.=vegetable; v.=very; w.=water; wh.=white. /1/ Superscripts in this column are temperatures at which determinations mycin B may be isomeric with carbomycin, and has the same antimicrobial spectrum.

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color[1]	Melting Point °C
15	Cycloserine (Isoxasolidone, p-4-amino-3-; Oxamycin; Seromycin)	Streptomyces garyphalus, n. spp; S. orchidaceus n. sp	Amphoteric	$C_3H_6N_2O_2$		Colorless cryst.; fine white needles	154-156
16	Erythromycin (Erythrocin, Ilotycin)	Streptomyces erythreus	Basic	$C_{37}H_{67-69}NO_{13}$ or $C_{38-39}H_{69-71}NO_{13}$	Not completely determined	White needles	Base: 136-140; HCl: 170-173
17	Erythromycin C	Streptomyces erythreus	Basic	$C_{36}H_{65}NO_{13}$	Similar to Erythromycin	Colorless needles	121-125
18	Framycetin (Actiline, Soframycine)	Streptomyces sp, similar to S. lavendulae	Basic	MW 1400-1500	Unknown	Chlorhydrate: white amorp. powder	Picrate: 189 d., corr.
19	Fumagillin (Fugillin, Amibex, Fumidil?)	Aspergillus fumigatus	Weak mono-basic acid	$C_{26-27}H_{34-36}O_7$	$[C_{16-17}H_{25-27}O_3]$-O-C=O (CH=CH)$_4$COOH	Colorless or light yellow crystals	189-194 d.
20	Gliotoxin (Aspergillin)	Aspergillus fumigatus, and several unrelated spp of fungi including Trichoderma viride		$C_{13}H_{14}N_2O_4S_2$		Colorless plates or needles	195 d.
21	Gramicidin[6] (A component of tyrothricin)	Bacillus brevis	Neutral polypeptide	Possibly $C_{148}H_{210}N_{30}O_{26}$	Unknown	Colorless platelets	228-231
22	Gramicidin S	Bacillus sp, similar to B. brevis	Cyclic decapeptide	MW 1060-1340	Uncertain	Thin colorless needles	268-270
23	Griseofulvin	Penicillium griseofulvum; other P. spp	Neutral	$C_{17}H_{17}O_6Cl$		Colorless rhombic or octahedral crystals	218-221
24	Neomycin A[7], B, C (Flavomycin)	Streptomyces fradiae; other S. spp	Basic	A: $C_{12}H_{26}N_4O_6$; B, C: $C_{23}H_{48}N_6O_{13}$ (proposed)	Unknown	A, base: white; HCl: white amorp, pwd.	A: 256 d.
25	Novobiocin (Cathomycin)	Streptomyces spheroides n.sp	Acid	MW 600-618	Incomplete	Nearly colorless	Polymorphic 153; 175
26	Nystatin (Fungicidin, Mycostatin)	Streptomyces noursei; S. fungicidicus	Amphoteric	$C_{46}H_{77}NO_{19}$ (proposed)	A tetraene	Yellow needles	160+ d. with out melting at 250
27	Oxytetracycline (Terramycin)	Streptomyces rimosus; S. platensis; S. armillatus	Amphoteric	$C_{22}H_{24}N_2O_9$		Pale yellow needles, thick hex. plates	Dihydrate: 181-182 d.; HCl: 190-194 d.
28	PA 114 A[8]	Streptomyces olivaceous	Neutral	$C_{25}H_{31}N_3O_6$ or $C_{25}H_{42}N_4O_9$	Unknown	Colorless needles	200 d.
29	Patulin (Clavacin, Clavatin, Claviformin, Expansine, Penicidin)	Penicillium spp; Aspergillus spp	Neutral	$C_7H_6O_4$		Colorless; rhombold plates, prisms	111-112
30	Penicillic acid	Penicillium spp; Aspergillus spp; synthesis	Monobasic acid	$C_8H_{10}O_4$		Colorless rhombic or hex. plates	Hydrate: 64-65; anhy. 86-87.

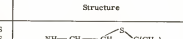
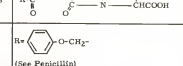
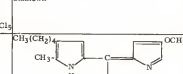
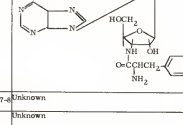
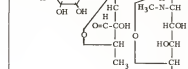
/1/ a.=acid; abs.=absolute; ac.=acetic; acet.=acetone; al.=alcohol; aliph.=aliphatic; alk.=alkali(ine); amorp.=amorphous; anhy.=anhydrous; aq.=aqueous; ether; filt.=filtrate; glac.=glacial; h.=hot; hex.=hexagonal; hydra.=hydrated; i.=insoluble; inact.=inactivated; lab.=labile; me., al.=methyl alcohol; min.=min-powder; pyr.=pyridine; rect.=rectangular; rm.=room; s.=soluble; sev.=several; sl.=slight; sol.=solution; solv.=solvent; st.=solvent; st.=stable; /6/ Gramicidin (20%+) and tyrocidin (80%+) are components of tyrothricin. /7/ Can be derived from B or C, and is identical with Neamine. /8/ PA

CHEMICAL CHARACTERISTICS (Continued)

Optical Activity[1,2] [α]D	Solubility[1]	Absorption Maxima,[1] UV, mμ	Stability[1]	Some Other Reactions[1]	
+116[25] in w.;+91[25] in NaOH	Dimerizes in solution.	226	Stable to alkali.	Pos. ninhydrin; 1 of the N exists as a primary amino group; α-(-)serine and hydroxylamine isolated from hydrolysates.	15
Base:-78[25] in al.;copp-plex:-476[25]	s.al., chl., acet.;less s.eth., w.,HClv.s.w., lower alcohols.	Base: 278 Complex: 274	st. at -25 to +4°C; st. 4 da at 37°C; unst. at 60-100°C.	One titratable group with pKa 8.6; activity not reduced by serum.	16
	Same as Erythromycin.	285 in me. al.	Similar to Erythromycin		17
Picrate: -32 in me. al.	Chlorhydrate: s.w., me.al.; i.acet., eth., most org.solv.		Thermostable.	No guanidinic grouping; all N as primary amine; forms picrate, reineckate; resembles streptomycin and neomycin, but differs from both.	18
-26.6[25] in me. al.	s. most org. solv., dil. alk.; i.w., dil. a.	239, 304, 322, 336, 351	Thermolabile; light sensitive.	Neg. $FeCl_3$, Millon, Fehling's, Molisch;properties change on exposure to air for one week.	19
-239 to -256 in chl.; -290±10[25] in al.	s.nc.a., acet., CCl_4, chl., dioxane, HCl, me.al.; sl.s.w., bz., al.	270, 450	st. to acids; unst. to alkali and light.	Readily oxidized with Br_2-water, forming sulfates; yields H_2S when reduced; black ppt. with lead acetate in boiling alkali; in alk. sol. decolorizes $KMnO_4$, giving a green color.	20
+320 in al.	s. lower alcohols, nc.a., pyr.; sl.s.abs.acet.;i.w., ether, hydrocarbons.	271, 281.5, 290.5	Thermostable.	Neg. Millon; pos. to most protein tests; hydrolyzed by acid; not digested by enzymes; forms a gel with picric acid.	21
-292[18] in al.	s.al., chl., acet.; less s. abs.al.; i.w., a., alk.		Thermo- and acid stable.	Positive ninhydrin, biuret; neg. Millon, xanthoprotein, Pauly, Volhard, Sakaguchi.	22
+370[17] in chl.; +337[21]in acet.	s.ac.a., dioxane, bz., eth., al., dimethyl formamide (12-14%); sl.s.chl., toluene; i.w., pet.eth.	236, 252, 291, 324	Thermostable.	Neg. $FeCl_3$, HBr, alk. Na nitroprusside, pyridine; yellow color with H_2SO_4 or HNO_3; reacted with phenylhydrazine, but not with diazomethane or semicarbazide. Solutions in dimethylformamide up to 1% can be diluted with H_2O without precipitating.	23
A, base: +112.8[25]in w.-HCl;+81[25]in al.	s.w.;sl.s.me.al.;i.other org. solv.	End absorption only.	Thermo-, acid and alkali stable.	Pos. ninhydrin, Molisch, carbasole; neg. glucosamine, Tollen's; yields furfural on acid hydrolysis; all N present as primary amino groups.	24
-63[24] in al.	s.al., me.al., acet.; i. w., chl.; Na salt s.w.	307 in 0.1N NaOH; 324 in 0.1N HCl in 90% me.al.	Thermostable.	Reacts as dibasic acid (pKa at about 4 and 9).	25
-102[5] in glac.ac.a.; -121[25]in pyr.	sl.s.al.me.al., dioxane; i w., pyr., glac.ac.a., dimethylformamide; pyr.	280, 291, 304, 318	st. in cold; unst. at pH 2 or 9.	Neg. $FeCl_3$, Millon; pos. Molisch; decolorizes $KMnO_4$. Br-CCl_4 in conc. H_2SO_4 color change from violet to blue to black.	26
Dihydrate: -196.6[25] in 0.1N HCl;-2.1[25] in 0.1N NaOH	s.a., alk.; sl.s.acet., al., chl., w.; i.eth.; HCl: s.w.; i.eth., pet.eth., bz.	270, 370 in me.al. Dihydrate: 249, 276, 353 in 0.1 M KH_2PO_4, pH 4.5.	st. at acid pH; decreasingly st. at pH 7 and above at 37°C.	Pos. $FeCl_3$, Pauly, Friedel-Crafts, Fehling's Molisch; HCl pKa 3.49, 7.55, 9.24 in aq. sol., forms complexes with inorg. salts; Ba-Ca and Ba-Mg very i. in w. and ppts. readily at pH 8.5-9.5.	27
-207 in me.al.	s.al., acet., bz.;sl.s. w.;i.pet.eth.	220-230, 275	Thermostable.	Green with $FeCl_3$; pos. copper acetate, Br_2 in CCl_4.	28
Inactive	s.w., al., acet., chl.eth., dil.alk.;i.pet.eth., bz.	276	Thermostable; rather labile to alkali.	Neg. $FeCl_3$, Schiff's; red color with alk.; yellow color with dil. ammonia, asparagine, amino acids; inhibited by serum, cysteine.	29
Inactive	s.h.w., al., eth., bz., chl.; i.pet.eth.	227	Stable.	No color with $FeCl_3$ in cold, orange-brown when heated; reddish-purple with strong ammonia on standing; no color with conc. H_2SO_4 or $NaNO_2$.	30

bz.=benzene; chl.=chloroform; colorl.=colorless; corr.=corrected; cryst.=crystalline; cult.=culture; d.=decomposes; def.=definite; dil.=dilute; eth.=ether; MP =melting point; MW = molecular weight; neg.=negative; org. =organic; pet. =petroleum; pos. positive; ppt. =precipitate; prop. =propylene; pwd. = powder; sl. =slightly; s. =soluble; sol. =solution; solv. =solvent; spar. =sparingly; st. =stable; unst. =unstable; veg. =vegetable; v. =very; w. =water; wh. =white. [2] Superscripts in this column are temperatures at which determinations were made.

114 B, with different chemical properties, is also formed during the fermentation.

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color[1]	Melting Point[1] °C
31	Penicillin(s)[9]	Penicillium notatum, Westling; Penicillium spp; Aspergillus spp	Strong monobasic carboxylic acids	F: $C_{14}H_{20}N_2O_4S$ G: $C_{16}H_{18}N_2O_4S$ K: $C_{16}H_{26}N_2O_4S$ X: $C_{16}H_{18}N_2O_5S$		Colorless prisms	Na salts: F: 204-205 d. G: 215 d. X: 228-235 d.
32	Penicillin V	Penicillium chrysogenum	Acidic	$C_{16}H_{18}N_2O_5S$	 (See Penicillin)	White crystals	120-128 d. (indefinite)
33	Polymyxin A, B, C, D, E (Aerosporin)	Bacillus polymyxa, various strains	Basic polypeptides	D: 4HCl: $C_{50}H_{97}$· $N_{15}O_{13}Cl_4H_3$· 5HCl: $C_{56}H_{104}N_{16}O_{14}Cl_5$	Unknown	Birefringent, no definite structure	228-235 d.
34	Prodigiosin	Serratia marcescens	Red pigment; monoacidic base	$C_{20}H_{25}N_3O$		Lustrous square pyramids; dark red with a green reflex	151-152
35	Puromycin (Stylomycin)	Streptomyces alboniger; synthesis	Diacidic base	$C_{22}H_{29}N_7O_5$		White crystals	Base: 175.5-177 (uncorr.)
36	Spiramycin (Rovamycin)	Streptomyces ambofaciens	Mixture of organic bases	$C_{22-24}H_{33-34}NO_{7-8}$	Unknown	Amorphous powder	
37	Streptolydigin	Streptomyces lydicus	Strong enol acid	$C_{32}H_{45}N_2O_9Br_3$	Unknown	Orthorhombic; yellow	144-150
38	Streptomycin	Streptomyces griseus; S. bikiniensis	Strong base	$C_{21}H_{39}N_7O_{12}$		Reineckate: thin plates; HCl: white amorp. pwd.; tri-HCl: monoclinic prisms	Reineckate: 164-165 d. Hellanthate: 220-226 d.
39	Streptothricin (See Neomycin)	Streptomyces lavendulae	Basic	$C_{13}H_{25}N_5O_7$, or $C_{20}H_{34}N_8O_9$?	Unknown	HCl and SO_4: wh. pwd.	Reineckate; 192-194 d.
40	Subtilin	Bacillus subtilis	Basic polypeptide	MW 3420 (found)	Unknown	Amorp. white pwd.	
41	Tetracycline (Achromycin, Panmycin, Polycycline, Steclin, Tetracyn)	Streptomyces spp. and reductive dehalogenation of chlortetracycline	Amphoteric	$C_{22}H_{24}N_2O_8$		Base: orthorhombic	anhyd.: 170-173 d.; HCl: 214
42	Thiolutin	Streptomyces albus	Neutral	$C_8H_8N_2O_2S_2$		Yellow needles	270 d.
43	Tyrocidine[3]	Bacillus brevis	Basic polypeptides	A: $C_{66}H_{87}N_{13}O_{13}$	Uncertain	HCl: colorless needles	A: 240-242 d.
44	Viomycin (Vinactin A)	Streptomyces floridae	Basic polypeptide	$C_{17-18}H_{31-35}N_7O_8$	Unknown	White crystals	SO_4: 280 d. anhyd.: 252 d.

/1/ a. = acid; abs. = absolute; ac. = acetic; acet. = acetone; al. = alcohol; aliph. = aliphatic; alk. = alkali(ine); amorp. = amorphous; anhy. = anhydrous; aq. = aqueous; bz. = filt. = filtrate; glac. = glacial; h. = hot; hex. = hexagonal; hydr. = hydrated; i. = insoluble; inact. = inactivated; lab. = labile; me. al. = methyl alcohol; min. = powder; pyr. = pyridine; rect. = rectangular; rm. = room; s. = soluble; sev. = several; sl. = slight; sol. = solution; solv. = solvent; st. = stable; unst. = un- /3/ Gramicidin (20%a) and tyrocidine (80%a) are components of tyrothricin. , /9/ For penicillin F, R = CH_3-CH_2=CH-CH_2-CH_2-; for G, R = -CH_2-

CHEMICAL CHARACTERISTICS (Concluded)

Optical Activity[1,2] $[\alpha]_D$	Solubility[1]	Absorption Maxima,[1] UV, $m\mu$	Stability[1]	Some Other Reactions[1]	
F: +276- 316$^{20-25}$in w.;G:301- 325^{25} in w.;K: +258^{25};[3] X: +267 in w.	Acids: s.al., eth., esters;sl. s.w.,sl.aliph.hydrocarb.;Na salts: s.w.,sl., me.al.;sl.s. ketones, ethylacetate.	G: 252, 257.5, 264 X: 278 F, K: no characteristic bands.	aq. sol. st. when pure; labile to acids, alk., heat, penicillinase.	Free acids hygroscopic, rapidly inactivated unless completely dry; inactivated by heavy metals; pptd. from sol. by aliphatic hydrocarbons; Na salts inact. in glac. ac. a., primary alcohols.	31
	s. eth., chl., al., me. al., acet.	268, 274 in water.	Free acid has much greater acid stability than other penicillins.		32
A, HCl: +422^{20} in w.; B_1 HCl: +402^{25} in w.	s.w., me. al.;less s. higher alcohols; i.eth., esters; base: sl. s.w.	No characteristic bands.	Thermo- and acid stable; alkali labile.	Pos. biuret, ninhydrin; neg. Molisch, Sakaguchi, Pauly; ppts. with picric, helianthic, flavianic, Reinecke acids.	33
	s.al., chl., eth., bromoform, bz.; i.w.	pH 7.4 in al., 225, 288, 337, 471, 539. pH 11 in al., 257, 281, 335, 468. pH 2.9 in al., 216, 296, 371, 541.	Thermostable.	Forms picrate, MP 176^{0}C; salicylate, MP 178^{0}C; benzoate, MP 170^{0}C; perchlorate, MP 228^{0}C (uncorr.).	34
-11^{25} in al.	HCl: s. lower alcohols, w.; sl.s.ethyl acetate; i.pet. eth., chl.; Base: s.aq. alcohols; i.w., eth., pet.eth.	275 in 0.1 N NaOH; 267.5 in 0.1 N HCl	Thermo- and pH stable.	Readily forms a dihydrochloride or monosulfate; neg. Brady's; infrared: 3309, 3200, 3125, 1645, 1600, 1560, 1512, 1428, 1403, 1345, 1303, 1248, 1230, 1184, 1158, 1107, 1070, 1040, 998, 968, 930, 871, 820, 791, 758 (recip. cm).	35
	sl.s.w.; s. most org. solv.	231-232		Silicotungstic acid → white ppt.; picric acid → yellow ppt.	36
-65,725^{25} in al. KOH	s. most org. solv.; i.w.; Na and K salts s.w.	262, 291, 335 in al. KOH; 357, 370 in al. H_2SO_4	Stable alk.; labile acid.	Pos. $FeCl_3$, iodoform; neg. Fehling's, Molisch, biuret, ninhydrin.	37
HCl: -84 in w.; SO_4: -79^{25} in w.; tri-HCl: -86.1$^{26.6}$ in w.	s.w.;less s.lower alcohols; i. other org. solv.	End absorption only.	Stable pH 3-7; less stable to hot, acid, alkali.	Maltol produced by alk. hydrolysis; inactivated by cysteine, reactivated by iodine; acid hydrolysis yields streptidine, streptobiosamine; pos. Sakaguchi; reacts rapidly with carbonyl group reagents.	38
-51,325in w.	HCl: s.w., dil. mineral a.; i. eth., pet, eth., chl.	End absorption only.	st. pH 1-8.5; thermolab. in cult. filt.	Pos. biuret, ninhydrin, Pauly; neg. $FeCl_3$, Molisch, Sakaguchi, Schiff's, Millon.	39
-29 to 353 in nc. a.	s.w., me.al., ac.a.; i. anhyd.al., acet., eth., chl.		Stable, esp. at pH 2.5.	Inact. by light, trypsin, me. al.; blue with $FeCl_3$; dialyzable.	40
-239^{25} in me. al.; -257.9^{25}in 0.1 N HCl	Trihydrate: sl. s.w.; HCl: s.w.	220, 268, 355 in 0.1 N HCl; 268, 363 in 0.01 M me. HCl. 246, 372 in 0.01 M me. NaOH.	st. in sol. at pH 7.0; 50% loss in 12 hr at pH 8.85; no loss in 0.1 N H_2SO_4 48 hr.	pKa 8.3, 10.2 in 50% aq. dimethylformamide; orange-yellow color with Ehrlich's in dil. HCl; chlortetracycline dehalogenated in presence of palladium yields tetracycline.	41
Inactive	s. most org. solv.; sl. s.w.	250, 311, 388 in me. al.	Acid stable; alkali labile.	Raney nickel treatment yields "desthiolutin" (MP 130-131^{0}C); acid hydrolysis yields an amine, $C_6H_6N_2OS_2$ (see aureothricin).	42
A: -101^{25} in al.	s. al., me. al., ac.a.; sl. s.w., acet.; i. eth., chl.	A: 290	Thermostable.	Pos. ninhydrin, Millon; red color with diazobenzenesulfonic acid; not digested by enzymes.	43
SO_4: -32 in w.	SO_4 and HCl: s.w.; i. most org. solv.	268 in 0.1 N HCl; 282.5 in 0.1 N NaOH 268.5 at pH 7	Very st. in acid; less st. in alk.	Pos. Sakaguchi, biuret, Fehling's, ninhydrin; neg. maltol, Molisch, Benedict's.	44

benzene; chl.=chloroform; color1.=colorless; corr.=corrected; cryst.=crystal(line); cult.=culture; d.=decomposes; def.=definite; dil.=dilute; eth.=ether; mineral; MP=melting point; MW=molecular weight; neg.=negative; org.=organic; pet.=petroleum; pos.=positive; ppt.=precipitate; prop.=propylene; pwd.=powder; s.=soluble; veg.=vegetable; v.=very; w.=water; wh.=white. /2/ Superscripts in this column are temperatures at which determinations were made. for K, R=$CH_3(CH_2)_6$-; and for X, R=

1 ACTINOMYCIN(S): IN VITRO: Inhibit some Gram-pos. and Gram-neg. bacteria, and certain fungi. IN VIVO: A inactive against Diplococcus pneumoniae and Streptococcus pyogenes infections in mice. Actinomycin C shows cytostatic activity against malignant tumors: Crocker sarcoma 180, Walker-carcinoma, mouse RC carcinoma. CLINICAL: C gave encouraging results in a few patients with lymphogranulomatosis. Inconclusive results in patients with a variety of inoperable malignant conditions.

2 AMICETIN: IN VITRO: Active against mycobacteria and Gram-pos. bacteria. IN VIVO: Active against Mycobacterium tuberculosis H37Rv in infected mice and against certain animal tumors. CLINICAL: Preliminary studies indicate that it is well tolerated in man when administered intramuscularly or intravenously.

3 AMIMYCIN: IN VITRO: Active against Gram-pos. bacteria, including mycobacteria. Active against some Gram-neg. bacteria (Hemophilus, Neisseria and Brucella), rickettsiae, large viruses, and large protozoa. CLINICAL: Effective in bacterial pneumonia and staphylococcal enteritis, especially in types resistant to other antibiotics. No serious side effects reported.

4 AMPHOTERICINS A and B: IN VITRO: Inhibits many pathogenic and saprophytic fungi. IN VIVO: B protected mice against systemic infection by Candida albicans, Histoplasma capsulatum, and Cryptococcus neoformans. Active against topical infection by Trichophyton mentagrophytes.

5 ANISOMYCIN: IN VITRO: Little or no antibacterial activity. Inhibits certain fungi, protozoa. IN VIVO: Active in Trichomonas foetus infection in mice. Protects guinea pigs from Entamoeba histolytica infection. CLINICAL: Favorable results vs Tr. vaginalis.

6 AUREOTHRICIN: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, mycobacteria and fungi. IN VIVO: Promoted growth of chicks with low concentration in diet; diet refused with increased concentration.

7 AZASERINE: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria, fungi and protozoa. IN VIVO: Active against Plasmodium lophurae in chicks, meningopneumonitis virus and Rickettsia prowazekii in chick embryos. Cytostatic activity against mouse leukemia, Crocker mouse sarcoma, carcinomas. No protection against Mycobacterium tuberculosis or viruses.

8 BACITRACIN(S): IN VITRO: In general, active against Gram-pos. bacteria with little or no activity against Gram-neg. organisms or fungi. IN VIVO: Protects against Clostridia, Micrococcus pyogenes var. aureus and Streptococcus pyogenes infections. Active against Borrelia duttoni in mice, Treponema pallidum in rabbits. Inhibited Plasmodium lophurae in chicks. Active against pinworms in mice. Promotes growth in chickens, turkeys, some plants. Increases fertility and egg production in hens.

9 CARBOMYCIN: IN VITRO: Active mainly against Gram-pos. and a few Gram-neg. bacteria, large viruses, rickettsiae, and certain protozoa. IN VIVO: Good protection against Diplococcus pneumoniae, Micrococcus pyogenes var. aureus, Pasteurella multocida, Clostridium tetani, many rickettsiae, viruses of psittacosis, ornithosis, lymphogranuloma venereum, human and feline pneumonitis, and sporadic encephalomyelitis. Inactive against Bacillus anthracis, Entamoeba histolytica, and Mycobacterium tuberculosis. CLINICAL: Useful vs infections, particularly from Gram-pos. organisms resistant to penicillin and other antibiotics. Good response in M. pyogenes var. aureus and Streptococcus pyogenes infections; also in pneumonia caused by D. pneumoniae and Str. pyogenes. Promptly cleared lesions of Treponema pallidum. Good response in amebic dysentery; may be of value in granuloma inguinale.

10 CELESTICETIN: IN VITRO: Active against Gram-pos. bacteria. Only slight activity against Gram-neg. bacteria and fungi. IN VIVO: Provides complete protection vs Streptococcus hemolyticus and Micrococcus aureus in mice; increased survival time of mice infected with Diplococcus pneumoniae (mortality ratio reduced). CLINICAL: Preliminary trials indicate it is well tolerated and relatively non-toxic.

11 CEPHALOSPORIN N: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria; weakly active against Mycobacterium tuberculosis.

12 CHLORAMPHENICOL: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria (including Mycobacterium tuberculosis), rickettsiae and larger viruses; no activity against fungi. Active against Entamoeba histolytica, Borrelia sp. Trypanosoma cruzi. IN VIVO: Protection in one or more laboratory animals against Bacillus anserina, B. bovyi, Klebsiella pneumoniae, Pasteurella multocida, Past. pestis, Plasmodium berghei, P. gallinaceum, Salmonella gallinarum, Shigella paradysenteriae, Vibrio comma, many rickettsiae, and the viruses of lymphogranuloma venereum and psittacosis. Only slight protection against Bacillus anthracis, Diplococcus pneumoniae, Erysipelothrix rhusiopathiae, Listeria monocytogenes, Mycobacterium tuberculosis, Streptococcus pyogenes, Str. viridans and most viruses. Showed an effect vs experimental pneumonia infections. CLINICAL: Useful in a wide variety of infections by susceptible microorganisms; especially valuable against Gram-neg. infections and the rickettsioses. Favorable results in typhoid fever, bacillary dysentery, cholera, gonorrhea, chancroid, lymphogranuloma venereum, granuloma inguinale, urinary and intestinal tract infections, bacterial pneumonia, epidemic and scrub typhus, Rocky Mt. spotted fever, Q fever, psittacosis, tularemia, primary atypical pneumonia, syphilis, relapsing fever, bartonellosis (Carrion's disease), non-specific urethritis, smallpox, yaws, and tropical ulcer. VETERINARY: Useful in a wide variety of infections, e.g., diarrhea of calves, colts and lambs; conjunctivitis, keratitis, and gastroenteritis in dogs. MISCELLANEOUS: Inhibited stone fruit virus in cucumber plants, and tobacco mosaic virus in tomato seedlings.

13 CHLORTETRACYCLINE: IN VITRO: Active against many Gram-pos. and Gram-neg. bacteria, rickettsiae, some viruses, and certain protozoa. Active against Actinomyces bovis, Histoplasma capsulatum. IN VIVO: Good protection in one or more laboratory animals against Bacillus anthracis, Bartonella muris, Borrelia duttoni, B. recurrentis, Diplococcus pneumoniae, Erysipelothrix rhusiopathiae, Escherichia coli, Hemophilus influenzae, Klebsiella pneumoniae, Listeria monocytogenes, Pasteurella multocida, Plasmodium gallinaceum, Proteus vulgaris, Salmonella typhi, Streptococcus pyogenes, and several spp of Clostridium; active in experimental leptospirosis, plague and histoplasmosis; also in most rickettsial infections, and viruses of psittacosis, Herpes zoster, rabies virus in mice, and lymphogranuloma venereum. No effect on Mycobacterium tuberculosis, or viruses of H. influenzae B, canine distemper, Newcastle disease, poliomyelitis, mumps, or foot and mouth disease. Inhibits development of Toshida ascites in rats. CLINICAL: Good response in bacillary infections by Aerobacter aerogenes, E. coli, Kleb. pneumoniae, Neisseria gonorrhoeae, Shigella spp; also in chancroid, granuloma inguinale, brucellosis, tularemia, streptococcal and D. pneumoniae infections, and sub-acute bacterial endocarditis. Highly effective in infections by most rickettsiae and larger viruses; also in primary atypical pneumonia. Useful in amebic and urinary tract infections, and in acute bronchitis, anthrax and otitis media. As effective as penicillin in secondary syphilis, yaws, and tropical ulcer. VETERINARY: Of value in bovine infections, e.g., calf scours, pneumonia, foot rot, vibriosis, chronic bloat, heartwater and mastitis; equine infections: strangles and septicemia; swine infections: dysentery, pneumonia, baby-pig diarrhea and pneumonia; small-fur animals: leptospirosis, coccidiosis, feline distemper, fowl typhoid, and topically for skin, eye, and ear infections. RESISTANCE: A considerable number of resistant strains of Micrococcus pyogenes var. aureus have emerged, in clinical experience this has not been a problem with other bacteria, e.g., Streptococcus spp, D. pneumoniae, Neisseria meningitidis and N. gonorrhoeae. MISCELLANEOUS: Wide usage as a growth stimulant for domestic and laboratory animals. Used as preservative for fish and poultry. Effective in control of crown gall tumor of tomato and other plants, and in many bacterial diseases of plants.

14 CYCLOHEXIMIDE: IN VITRO: Little or no effect on bacteria. Affects some phytopathogenic fungi, particularly yeasts, but most fungi pathogenic to animals are not susceptible, although Cryptococcus neoformans, Blastomyces dermatitidis, and Histoplasma capsulatum are inhibited. Active against Trypanosoma cruzi and Trichomonas sp. IN VIVO: Effective in control of some experimental amebiasis (Entamoeba histolytica), CLINICAL: Good response in a single patient with meningitis caused by Coccidioides immitis, and in a case of Cryptococcus neoformans meningitis. MISCELLANEOUS: Good control of powdery mildew and cherry leaf spot, but toxic for some plants. Effective as a rat repellant.

15 CYCLOSERINE: IN VITRO: Inhibits Mycobacterium tuberculosis (including strains resistant to isoniazid, pyrazinamide, and p-aminosalicylic acid); Gram-pos. and some Gram-neg. bacteria are inhibited only with high concentrations which also inhibit some fungi. IN VIVO: Relatively inactive against Myco. tuberculosis infection in mice; synergistic with dihydrostreptomycin. Good protection against Diplococcus pneumoniae, Escherichia coli, Klebsiella pneumoniae, Micrococcus pyogenes var. aureus, Pseudomonas aeruginosa, Salmonella schottmuelleri, and Shigella sonnei in preliminary trials vs advanced pulmonary tuberculosis refractory to other agents. Good response in urinary infections by Aerobacter aerogenes, E. coli, Proteus, and Pseudomonas.

16 ERYTHROMYCIN: IN VITRO: Active primarily against Gram-pos. bacteria, but a few Gram-neg. organisms, certain rickettsiae and larger viruses are susceptible. Active against Entamoeba histolytica, Borrelia sp. and Trichomonas vaginalis. IN VIVO: Good protection against Corynebacterium diphtheriae, Diplococcus pneumoniae, Entamoeba histolytica, Streptococcus pyogenes; moderate protection against Hemophilus pertussis, Micrococcus pyogenes var. aureus, Listeria monocytogenes, Trypanosoma equiperdum. Not effective against Bacillus anthracis, Erysipelothrix rhusiopathiae, Klebsiella pneumoniae, Salmonella gallinarum, Trypanosoma cruzi, or rabies, poliomyelitis, lymphocytic choromeningitis, influenza viruses. CLINICAL: Useful in infections by organisms resistant to penicillin and tetracycline. Highly effective in pneumococcus pneumonia and in infections by micrococci and streptococci, including pharyngitis, tonsilitis, scarlet fever and cellulitis. Favorable as well as indifferent results in gonorrhea, lymphogranuloma venereum, chancroid and donovanosis. Good responses in primary and secondary syphilis, trachoma, surgical infections and infections by E. histolytica. Topical therapy useful in acute pyoderma and acne vulgaris. VETERINARY: Effective in control of canine pneumonia, bronchitis, pyogenic surgical infections, otitis media and early cases of distemper. RESISTANCE: No significant cross-resistance between erythromycin and penicillin or most other antibiotics except carbomycin.

17 ERYTHROMYCIN B: IN VITRO: Antimicrobial spectrum similar to erythromycin.

18 FRAMYCETIN: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria (including mycobacteria); low activity against fungi. CLINICAL: Topical therapy effective against staphylococcal infections.

19 FUMAGILLIN: Little or no activity against bacteria and fungi; active against certain protozoa and viruses. IN VITRO: Inhibits Entamoeba histolytica and Trichomonas vaginalis. Active against bacteriophages. In tissue cultures virucidal to eastern and western equine encephalitis, slightly active against influenza PR8, inhibits poliomyelitis (Lansing strain). IN VIVO: Highly active in experimental amebiasis; inactive against Borrelia novyi, Trypanosoma cruzi, T. equiperdum, and T. gambiense. No antiviral activity in mice with poliomyelitis (MM strain), influenza A, or swine influenza viruses. CLINICAL: Cleared majority of human E. histolytica cyst passers. Generally favorable results vs chronic intestinal amebiasis.

20 GLIOTOXIN: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria and some fungi. Inactivates Gardner lymphosarcoma and various transplantable carcinomas of mice and rabbits. Sarcoma 180 implants rendered innocuous in mice. IN VIVO: No protection in mice against Streptococcus pyogenes, nor in experimental mouse tuberculosis. Post-treatment in mice failed to suppress implants of Sarcoma 180. MISCELLANEOUS: Control in covered barley smut and wheat bunt; seed protective.

21 GRAMICIDIN: Primarily active against Gram-pos. bacteria. IN VITRO: Active in low concentrations against a wide variety of Gram-pos. bacteria, some Gram-neg. organisms inhibited in higher concentrations. IN VIVO: Small intraperitoneal injections gave high protection against Bacillus anthracis, Clostridium perfringens, Diplococcus pneumoniae, Micrococcus pyogenes var. aureus and Plasmodium gallinaceum. CLINICAL: Parenteral toxicity of gramicidin (for tyrothricin q.v.) precludes use in systemic infections. Topical therapy may be beneficial.

22 GRAMICIDIN S: IN VITRO: Antimicrobial spectrum similar to that of gramicidin. IN VIVO: Good protection against Clostridium perfringens infections. CLINICAL: Used topically in skin infections, empyema, with favorable results.

23 GRISEOFULVIN: IN VITRO: Antifungal. Inhibits numerous spp of zygomycetes, ascomycetes, basidiomycetes and fungi imperfecti. UTILIZATION: Protects plants against several phytopathogenic fungi.

24 NEOMYCIN: IN VITRO: Active primarily against Gram-pos. (including mycobacteria) and Gram-neg. bacteria and actinomycetes; little activity against fungi, viruses, or protozoa. IN VIVO: Good protection in experimental murine tuberculosis and against streptomycin-resistant strains of Mycobacterium tuberculosis. High protection against Bacillus anthracis, Hemophilus influenzae, Klebsiella pneumoniae, Micrococcus pyogenes var. aureus, Pasteurella multocida, Proteus vulgaris, Salmonella choleraesus, S. gallinarum, S. schottmuelleri, S. typhi, S. typhimurium, Vibrio comma, and in experimental bubonic and pneumonic plague. Active against Hemophilus pertussis and Salmonella pullorum in embryonated eggs. CLINICAL: Effective pre-operative intestinal antiseptic. Of value in bacillary dysentery, amebiasis, and epidemic infantile diarrhea. Favorable results following topical therapy for many skin and ocular infections. Instillation favorable in cervicitis and vaginitis by Proteus spp. in non-gonococcal urethritis, peritonitis. Beneficial results in tuberculosis, nephro- and ototoxicity after prolonged parenteral administration limit usefulness. VETERINARY: A variety of gastrointestinal infections in domestic animals respond to oral therapy.

25 NOVOBIOCIN: IN VITRO: Active primarily against Gram-pos. bacteria, although a few Gram-neg. bacteria are inhibited. Active against strains resistant to commercially available antibiotics including penicillin. IN VIVO: Good protection against Micrococcus pyogenes var. aureus, Streptococcus pyogenes, Diplococcus pneumoniae, Hemophilus pertussis, Proteus vulgaris, Pasteurella avicida, Neisseria meningitidis. No protection against Klebsiella pneumoniae, Escherichia coli, Salmonella typhi, S. schottmuelleri, Shigella dysenteriae. No evidence of antituberculosis or antifungal activity in experimentally infected mice. No demonstrable activity against rickettsiae, viruses or protozoa in mice. Equally active orally or subcutaneously.

26 PUNGICIDIN: Active against fungi. IN VITRO: Inhibits many fungi. IN VIVO: Protects mice against Candida albicans, Coccidioides immitis, Cryptococcus neoformans, Histoplasma capsulatum and Sporotrichum beurmanni. CLINICAL: Reduced number of C. albicans in fecal flora. Counteracts increase in gastrointestinal yeast flora accompanying oral tetracycline therapy. Oral doses effective against a variety of monilial infections.

27 OXYTETRACYCLINE: IN VITRO: Active against many Gram-pos. and Gram-neg. bacteria, actinomycetes, rickettsiae, larger viruses, and certain protozoa, no activity against fungi. IN VIVO: High protection in one or more laboratory animals against Bacillus anthracis, Borrelia anserina, B. duttoni, B novyi, most Clostridium spp, Diplococcus pneumoniae, Hemophilus influenzae, Klebsiella pneumoniae, Micrococcus pyogenes var. aureus, Pasteurella multocida, Proteus, tularensis, Salmonella choleraesuis, S. enteritidis, S. typhi, S. typhimurium, Streptococcus pyogenes, and Vibrio comma. Active against Bartonella muris, Plasmodium spp. Suppressive effect against Brucella melitensis. Highly active against most rickettsiae, gray lung virus in mice and experimental feline pneumonitis virus. Effective in experimental rabbit syphilis, but less active on weight basis than penicillin. CLINICAL: Highly effective in treatment of infections by streptococci, micrococci, bacteriodes, brucellae, D. pneumoniae, and in urinary tract infections. Useful for pre- and post-operative prophylaxis in bowel surgery, peritonitis, respiratory infections. Highly effective in most rickettsial diseases, psittacosis, lymphogranuloma venereum, granuloma inguinale and in amebic dysentery. Very effective in gonorrhea; preliminary trials in syphilis gave variable results. Favorable response in yaws, primary stypical pneumonia, Plasmodium falciparum malaria and P. vivax. Excellent response in punworm infestation (Enterobius vermicularis), Balantidium coli infection and non-gonococcal urethritis have been treated with good results. Meningitis caused by H. influenzae or Neisseria meningitidis responded favorably. Topical therapy is effective in skin and ocular infections, including trachoma. VETERINARY: Good results vs mastitis, anaplasmosis, pneumoenteritis and metritis in cattle; necrotic enteritis in swine; chronic respiratory disease, infectious sinusitis and salmonellosis in poultry; pneumonia, wound infections, in dogs; pleuropneumonia in goats. RESISTANCE: Clinically, resistance strains of M. pyogenes var. aureus have emerged, but this has not become a problem with other bacteria. Organisms developing resistance generally exhibit cross-resistance to other tetracycline antibiotics. MISCELLANEOUS: Useful vs many bacterial diseases of plants. Growth stimulant for domestic and laboratory animals. Preservative for fish, poultry, vegetables and fruits.

28 PA 114, A and B: IN VITRO: A and B show independent activity against Gram-pos. bacteria including a wide variety of Micrococcus pyogenes var. aureus strains resistant to penicillin and other antibiotics. A and B synergize when combined in appropriate percentage combinations. IN VIVO: A and B separately showed high protection against Streptococcus pyogenes infections in mice. Mixtures, ranging from 1% of one to 99% of the other, showed a marked increase in activity. A partly purified product containing A and B in ratios produced during fermentation showed good protection against Streptococcus pyogenes, Diplococcus pneumoniae, and both normal and resistant strains of Micrococcus pyogenes var. aureus. No activity against yeasts or filamentous fungi. RESISTANCE: Similar to that shown by penicillin.

29 PATULIN: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, fungi. IN VIVO: Inactive against all bacteria and viruses tested. CLINICAL: Ointment of slight value in skin infections.

30 PENICILLIC ACID: IN VITRO: Active against some Gram-pos. and Gram-neg. bacteria, plant pathogenes and fungi.

31 PENICILLIN: IN VITRO: In general, highly active against Gram-pos. bacteria. Although some resistant strains are encountered, most strains of the following genera are sensitive to low concentrations: Bacillus, Cloatridium, Corynebacterium, Diplococcus, Micrococcus, Streptococcus and Actinomyces. Spp of Borrelia, Leptospira and Treponema are highly sensitive. Excepting strains of Hemophilus and Neisseria, many of Gram-neg. strains are not sensitive, e.g., Aerobacter, Escherichia, Klebsiella, Pasteurella, Proteus, Pseudomonas, Salmonella, Shigella and Vibrio spp. Inactive against Mycobacterium spp, pleuropneumonia-like organisms, yeasts, fungi, viruses, rickettsiae and protozoa. IN VIVO: Activity in experimental infections similar to that of the IN VITRO antimicrobial spectrum. CLINICAL: Indicated in a wide variety of infections by susceptible organisms. Value established in veterinary practice. RESISTANCE: Has taken on proportions of a serious clinical problem only with Micrococcus pyogenes. The clinically isolated resistant strains are generally penicillinase producers, in contrast to the temporary resistance produced IN VITRO.

32 PENICILLIN V: IN VITRO, IN VIVO: Activity similar to that of penicillin. CLINICAL: Free acid, when given orally, yields higher blood levels than does penicillin G.

33 POLYMYXIN(S): IN VITRO: Active mainly against Gram-neg. bacteria, many of which are inhibited at low concentrations. At higher concentrations some Gram-pos. bacteria are sensitive. IN VIVO: Good protection against Hemophilus pertussis, Klebsiella pneumoniae, Pasteurella multocida, Salmonella gallinarum, S. typhi. CLINICAL: Promising results vs Aerobacter aerogenes bacteremia, pertussis, acute brucellosis, Kleb. pneumoniae infections. Nephro- and neurotoxicity probably caused by impurities; purified preparations of polymyxin B and E seem to be safe intramuscularly. Pseudomonas aeruginosa infections, especially of the urinary tract, respond to treatment with B when other antibiotics have been ineffective. Oral therapy is of value in certain gastrointestinal infections. MISCELLANEOUS: Skin histamine released at areas remote from site of subcutaneous injections of B or E in rats.

34 PROPIGIOSIN: IN VITRO: Active against certain fungi and protozoa; little or no activity against bacteria. IN VIVO. Slight activity in mice infected with Diplococcus pneumoniae and Micrococcus pyogenes var. aureus. Oral doses in rodents prevented Entamoeba histolytica, Trypanosoma brucei and T. equiperdum infections. CLINICAL: Encouraging results in a few patients having disseminated coccidioidomycosis.

35 PUROMYCIN: IN VITRO: Active against certain Gram-pos. and Gram neg. bacteria, and protozoa. IN VIVO: Suppressed Trypanosoma cruzi and T. equiperdum infections. Good protection against T. equinum, T. evansi, T. gambiense, T. rhodesiense; little or no activity against T. congolense. Effective against Entamoeba histolytica and Toxoplasma gondii. Highly effective against mouse oxyuride (Aspiculuris tetraptera and Syphacia obvelata); partly suppressed tapeworm (Hymenolepis nana var. fraterna) in mice. Active against transplanted mouse mammary adenocarcinoma. Slightly effective against mouse sarcoma 180. No effect vs mouse or rat leukemias. CLINICAL: Effectively controlled T. gambiense and E. histolytica infections. Slight to moderate tumor regression in a few patients with disseminated or advanced incurable neoplastic disease.

36 SARKOMYCIN: IN VITRO: Inhibits Bacillus anthracis, Micrococcus pyogenes var. aureus, Salmonella typhi, S. paratyphi, S. schottmuelleri, Proteus vulgaris, Pseudomonas aeruginosa, Mycobacterium spp. Nocardia asteroides. Antifungal activity vs Histoplasma capsulatum, Trichophyton mentagrophytes, Torula utilis, Cryptococcus neoformans, Saccharomyces sake, Aspergillus niger, Penicillium chrysogenum. IN VIVO: Prolonged survival time in rats with Yoshida sarcoma and in mice with Ehrlich carcinoma. CLINICAL: Clinical improvement in 26 of 78 cases with inoperable carcinoma; no serious side effects observed.

37 SPIRAMYCIN: Principally active against Gram-pos. bacteria, particularly staphylococci resistant to the usual antibiotics. Inhibits streptococci, corynebacteria, neisseria, and certain strains of clostridia. Also active against some rickettsiae. Little activity against myco- and enteric bacteria. CLINICAL: Effective against respiratory, staphylococcal, streptococcal and gonococcal infections, virus pneumonia and exanthematic typhus.

38 STREPTOLYTIGIN: IN VITRO: Active against Gram-pos. bacteria, particularly species of Clostridium, Diplococcus, Streptococcus, and Mycobacterium. Also active against Pasteurella multocida. Slight antifungal activity. IN VIVO: Effective both orally and subcutaneously in mice infected with Streptococcus hemolyticus, Diplococcus pneumoniae and Pasteurella multocida.

39 STREPTOMYCIN: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, including mycobacteria. No activity against fungi, rickettsiae, or viruses. IN VIVO: Excellent protection is afforded in a wide variety of experimental infections, including Bacillus anthracis, Brucella abortus, Diplococcus pneumoniae, Micrococcus pyogenes var. aureus, Mycobacterium tuberculosis, Neisseria meningitidis, Pasteurella pestis, Past. tularensis, Streptococcus pyogenes, and spp of Hemophilus, Klebsiella, Pseudomonas, Salmonella, Shigella. CLINICAL: Used with success in tuberculosis, bacteremia, meningitis, pneumonia caused by Klebsiella pneumoniae, empyema and other pulmonary conditions, chancroid, tularemia, plague, glanders, skin infections by Proteus vulgaris, peritonitis and enteritis, corneal ulcers from Pseudomonas aeruginosa. RESISTANCE: Strains of Myco. tuberculosis may develop resistance very rapidly. The emergence of resistant strains of other organisms has also been noted, e.g., the majority of strains now being clinically isolated of Aerobacter aerogenes, Pseudomonas aeruginosa, Proteus vulgaris, and Streptococcus fecalis are resistant. MISCELLANEOUS: Widely used in agriculture vs several diseases including fire blights.

40 STREPTOTHRICIN: Active against Gram-pos. and Gram-neg. bacteria and certain fungi. IN VIVO: Active against Brucella abortus, Escherichia coli, Pasteurella tularensis, Salmonella schottmuelleri, S. typhi, Shigella dysenteriae. No protection against Diplococcus pneumoniae, Pasteurella pestis, Proteus vulgaris, Pseudomonas aeruginosa, and Streptococcus pyogenes. No activity in experimental tuberculosis of guinea pigs or hamsters. Suppressed Blastomyces dermatitidis in chick embryos. RESISTANCE: IN VITRO: Resistance develops fairly rapidly. Resistant strains frequently display cross-resistance to streptomycin and neomycin.

41 SUBTILIN: IN VITRO: Active mainly against Gram-pos bacteria and some fungi. Also active against bacteriophages. IN VIVO: Active experimentally against Bacillus anthracis, Diplococcus pneumoniae, Micrococcus pyogenes var. aureus, Streptococcus pyogenes in mice. Inactivated influenza PR8 and Newcastle disease viruses in embryonated eggs. Activity against Rickettsia tautsugamushi, but less effective against Rickettsia rickettsi in chick embryos. MISCELLANEOUS: Used as a feed supplement for enhanced growth of chicks. May prove useful as a food preservative.

42 TETRACYCLINE: IN VITRO: Active against many Gram-pos and Gram-neg. bacteria, certain protozoa. IN VIVO: Good protection against Diplococcus pneumoniae, Klebsiella pneumoniae, Micrococcus pyogenes var. aureus, Pasteurella multocida, Salmonella typhi, Streptococcus mitis, Str. pyogenes. Some protection vs experimental tuberculosis in mice. Large doses suppressed Bacillus anthracis and Listeria monocytogenes, as well as virus of primary atypical pneumonia. CLINICAL: Effective in a wide variety of diseases including pneumonia, scarlet fever, otitis media, acute pharyngitis, sinusitis, osteomyelitis, laryngotracheobronchitis, meningitis, and in surgical infections and infections of the urinary tract and soft tissues. Excellent results vs acute gonorrhea. Favorable response vs non-gonococcal urethritis, acute or chronic brucellosis, lymphogranuloma venereum, donovanosis, chancroid, psittacosis, exanthematic typhus, Rocky Mt. spotted fever, acute amebiasis, bartonellosis (Carrion's disease), and bacillary dysentery caused by Shigella sonnei. Successful vs a variety of skin infections, and in trachoma. Appeared to benefit 36 of 45 patients with infectious hepatitis. VETERINARY: Effective vs mastitis, shipping fever complex and pneumonia in cattle, pneumonia-enteritis complex, mastitis and listeriosis in sheep; infectious scours and pneumonia in swine; distemper in cats; pneumonia, bacillary enteritis and distemper complex in dogs, psittacosis in parakeets. RESISTANCE: IN VITRO: Resistance developed in Escherichia coli and M. pyogenes var. aureus, pattern similar to that of penicillin, and in contrast to that of streptomycin. Cross-resistance to other tetracyclines.

43 THOLUTIN: IN VITRO: Active against some Gram-pos. and Gram-neg. bacteria, fungi, and protozoa. IN VIVO: Slight suppressive effect experimentally vs Trypanosoma cruzi in mice, but toxic at doses administered. No activity against Plasmodium gallinaceum in chicks. MISCELLANEOUS: Sprays useful in control of apple tree fire blight and late blight of potato. Controls tomato wilt by Bacterium lycopersici. Improved germination of oat grain infected with Helminthosporium avenum.

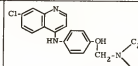
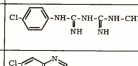
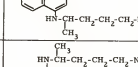
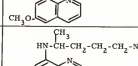
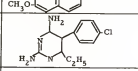
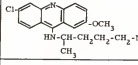
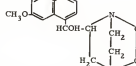
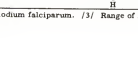
44 TYROCIDINE: IN VITRO: Principally inhibits Gram-pos. bacteria, some protozoa. IN VIVO: In mice, exhibits little or no effect vs Clostridium perfringens or Micrococcus pyogenes var. aureus infections, and no activity against Trypanosoma cruzi.

45 TYROTHRICIN: IN VITRO: Active against some Gram-pos. and some Gram-neg. bacteria, certain fungi, spirochetes and protozoa. IN VIVO: In experimental infections protects against Bacillus anthracis, Clostridium perfringens, Diplococcus pneumoniae, Micrococcus pyogenes var. aureus, Plasmodium gallinaceum, Streptococcus pyogenes. CLINICAL: Toxicity precludes parenteral use, is ineffective orally. Used topically with success vs superficial indolent ulcers, mastoiditis, empyema, and wound infections when the predominating organisms are susceptible Gram-pos. bacteria. Effective vs tonsillitis, otitis, dermatoses, infected ulcers and burns, and infections of the eye and conjunctiva. Inhalation of an aerosol beneficial in various forms of bronchitis, in rhinopharyngitis and allergic rhinitis. Favorable results reported in treatment of puerperal mastitis by M. pyogenes var. aureus. VETERINARY: Of value vs acute and chronic mastitis in cattle, in topical treatment of infected wounds, canine dermatoses, sarcoptic mange, ear mites of dogs, cats, and rabbits, and leg mange of birds.

46 VIOMYCIN: IN VITRO: Inhibits some Gram-pos. and Gram-neg. bacteria and Mycobacterium tuberculosis (including strains resistant to streptomycin and neomycin). IN VIVO: Good protection vs Myco. tuberculosis. Strains sensitive or resistant to streptomycin equally responsive to viomycin. Protects vs Bacillus anthracis, Klebsiella pneumoniae, Pasteurella multocida, Proteus vulgaris, Salmonella gallinarum, S. typhi. Some activity vs mouse leprosy bacilli (Mycobacterium lepraemurium). Suppressed Rickettsia typhi in embryonated eggs. CLINICAL: Effective in treatment of tuberculosis, but usefulness limited as its activity is less impressive than that of streptomycin or isoniazid and because of its toxic potentialities. RESISTANCE: Myco. tuberculosis may develop resistance. Strains resistant to streptomycin or neomycin not cross-resistant to viomycin.

	Common Name and Synonyms	Empirical Formula, Melting Point °C[1]	Solubility[1]	Structure	Acute Oral Toxicity mg/kg	Activity in vitro µg/ml	Activity against Amebiasis in Laboratory Animals: Intestinal	Hepatic	Side Effects
1	Diiodohydroxyquinoline (Diodoquin)[2]	$C_9H_5I_2NO$ MP = 200-215 d.	i. w.; sl. s. al., eth., acet.; s. pyr., dioxane	R_1=I R_2=H	LD_{50} 5000 (mouse)	200-1000	Cat, dog, guinea pig, rabbit, rat.		Diarrhea.
2	Chinoifon (Yatren)[2]	$C_9H_6NO_5S$ MP = 244-250 d.	i. w.; sl.; s. alk.	R_1=SO_3H(+Na salt) R_2=H	LD_{50} 900 (guinea pig)	100-3000	Cat, dog, guinea pig, hamster, monkey, rat.		Diarrhea, nausea and vomiting; skin rash.
3	Iodochlorohydroxyquinoline (Vioform)[2]	C_9H_5ClINO MP=172 d.	i. w.; s. al., chl., ac. a.	R_1=I R_2=Cl	LD_{50} 175 (guinea pig), LD_{50} 400 (cat)	125	Cat, dog, guinea pig, monkey, rat.		Diarrhea and abdominal pain; agranulocytosis.
4	Carbarsone[2]	$C_7H_8AsN_2O_4$	sl. s. w., al.; i. eth., chl.; s. alk.	R_1=H R_2=$NHCOCH_3$	MLD 200 (guinea pig), MLD 150 (rabbit)	125-3300	Cat, dog, guinea pig, hamster, monkey, rabbit, rat.		Arsenic reactions (rarely); diarrhea, nausea; skin rash.
5	Diaphetarsine[2]	$C_{14}H_{18}As_2N_2O_6$ MP=above 250	s. alk.	R_1=H R_2=$NH(CH_2)_2NH$ AsO_3H_2	LD_{50} 5000 (mouse), LD_{50} 2500 (rat)		Rat.		
6	Thiocarbarsone (C.C. 914)	$C_{11}H_{13}AsS_2N_2O_5$ MP=83-84	sl. s. w.; s. alk.	H_2N-CO-HN- As(S-CH_2-COOH)$_2$	LD_{50} 1000 (rat)	20-100	Monkey.	Hamster.	Gastrointestinal.
7	Bismuthoxy-glycolyl-arsanilate (Milibis; Glycobiarsol)[2]	$C_8H_6AsBiNO_6$ MP=d.	i. most solvents.	$BiHO_4As$ NH-CO-CH_2OH	Tolerated at 10,000 (rat)	33	Cat, hamster.		Arsenic reactions (rarely); diarrhea and abdominal pain; skin rash.
8	Emetine[3]	$C_{29}H_{40}N_2O_4$ MP=233-238 (2HCl·7H_2O) MP=68 MP=74 (base)	s. al., chl., eth.; sl. s. w. (base).	CH_3O, CH_3O, C_2H_5, HN, CH_2, OCH_3, OCH_3	LD_{50} 30 (mouse)	0.5-31	Guinea pig, monkey, rat.	Hamster.	Diarrhea; dizziness; weakness and tenderness of skeletal muscles; damage to heart muscle.
9	Conessine (Wrightine; Nevine)[2]	$C_{24}H_{40}N_2$ MP=340 (2HCl) MP=125 (base) MP=222-224 (picrate)	sl. s. w.; s. acet., al.	$N-CH_3$, H_2C, $CH-CH_3$, H_3C, $(CH_3)_2N$			Rat.		Central nervous system (tremors, hallucinations, nervousness).
10	Biallylamicol (Camoform)[2]	$C_{28}H_{40}N_2O_2$ MP=210-212 (2HCl)	s. w.	CH_2=$CHCH_2$, CH_2CH=CH_2, HO, OH, $(C_2H_5)_2CH_2$, $CH_2N(C_2H_5)_2$	LD_{50} 3840 (mouse), LD_{50} 1706 (rat)	40-134	Dog, rat.	Hamster.	Gastrointestinal; skin rash.
11	Chlortetamide (Mantomide; Win 5047; Letrenol)[2]	$C_{11}H_{11}Cl_4NO_2$ MP=110-113	i. w., eth.; s. al.	Cl, $CH_2NCOCHCl_2$, Cl, CH_2CH_2OH	LD_{50}>16,000 (mouse)	6.25-7.8	Hamster, rat, monkey.		
12	Chlortetracycline (Aureomycin)[2, 4]	See Table for physical and chemical properties.				29-250	Dog, guinea pig, monkey, rabbit, rat.	Hamster (slight).	Gastrointestinal; proctitis.
13	Erythromycin (Ilotycin; Erythrocin)[2, 4]	See Table for physical and chemical properties.				1000->1000	Monkey, rat.		Gastrointestinal.
14	Fumagillin (Fumidil)[2]	$C_{26-27}H_{34-36}O_7$ MP=189-194	i. w.; s. organic solvents, alk.	$(C_{16-17}H_{25-27}O_3)$ -OCO(CH=CH_4-COOH		0.07-0.13	Dog, guinea pig, monkey, rabbit, rat.		Gastrointestinal; vertigo; leucopenia; skin rash.
15	Oxytetracycline (Terramycin)[2, 4]	See Table for physical and chemical properties.				133-400	Dog, guinea pig, monkey, rabbit, rat.	Hamster (slight).	Gastrointestinal; proctitis.

/1/ Abbreviations: ac.a.=acetic acid; acet.=acetone; al.=ethyl alcohol (95%); alk.=alkali; chl.=chloroform; d.=decomposes; eth.=ether; i.=insoluble; pyr.=pyridine; s.=soluble; sl.=slightly; w.=water.
/2/ Active in intestinal amebiasis. /3/ Active in hepatic amebiasis. /4/ Probably active in an indirect manner.

	Common Name and Synonyms	Empirical Formula, Molecular Weight, Melting Point, °C	Structural Formula	Oral Toxicity: Mouse LD_{50} mg/kg	Maximum Tolerated Dose: Dog mg/kg/da	Maximum Tolerated Dose: Monkey mg/kg/da	Maximum Tolerated Dose: Man g/da	Type of Activity: Prophylaxis P. vivax[1]	Prophylaxis P. falc.[2]	Supression, Active Infection P. vivax[1]	Supression, Active Infection P. falc.[2]	Control of Acute Attack P. vivax[1]	Control of Acute Attack P. falc.[2]	Eradication of Infection P. vivax[1]	Eradication of Infection P. falc.[2]
1	Amodiaquin (Camoquin, CAM-AQI, Miaquin, SN 10,751)	$C_{20}H_{22}Cl\,N_3O$ MW = 355.86 MP = 208			40	25-50	0.3	-	-	++++	++++	++++	++++	- .	++++
2	Chlorguanide (Guanatol, Paludrine, Palusil, Proguanil)	$C_{11}H_{16}Cl\,N_5$ MW = 253.7 MP = 135		24-70[3]	10-20	40-80	1.0	± to -	+	++	++ to ±	++	+ to ±	-	+ to ±
3	Chloroquine (Aralen, Nivaquine B, Resochin, SN 7618)	$C_{18}H_{26}Cl\,N_3$ MW = 319.88 MP = 87		752	12	25-50	0.3	-	-	++++	++++	++++	++++	-	++++
4	Pamaquine (Plasmochin, Plasmoquine, Praequine)	$C_{19}H_{29}N_3O$ MW = 305.4 MP = 187-189 boils 0.2 mm		68	3	6	0.06[4]	+ to ±	+ to ±	-	-	-	-	+	-
5	Primaquine (SN13,272)	$C_{15}H_{21}N_3O$ MW = 259.34 MP = 175-179 boils 0.2 mm		51	3	12	0.09	++ to ±	?	?	?	-	-	++	-
6	Pyrimethamine (Daraprim, BW 50-63)	$C_{12}H_{13}Cl\,N_4$ MW = 248.7 MP = 233-234		92	5± i.v.[5]	2.5	0.025	+	++	+++	+++ to ±	++	++ to ±	+ to ±	++ to ±
7	Quinacrine (Atabrine, Atebrin, Erion, Mepacrine)	$C_{23}H_{30}Cl\,N_3O$ MW = 399.77		510-800[4]	40-80	50	0.2	-	-	++	++	++	++	-	++
8	Quinine	$C_{20}H_{24}N_2O_2$ MW = 324.41 MP = 175-177		350-950[4]	80	480	2.0	-	-	+	+	+	+ to ±	-	+ to ±

/1/ Plasmodium vivax. /2/ Plasmodium falciparum. /3/ Range of means reported by different investigators. /4/ Three divided doses. /5/ Intravenously.

	Common Name	Chemical Name	Formula	Molecular Weight	Crystalline Form, Color, Density (d)	Melting Point °C	Solubility[1]	Lethal Dose (mg/kg)[2] and Relative Effectiveness[3]			
								Norway Rats	Roof Rats	House Mice	Other Rodents
1	ANTU	Urea, 1-(1-naphthyl)-2-thio-	$C_{11}H_{10}N_2S$	202.27	Gray prisms from al.	198	i.w., eth.; s. h.al.	6-8 (+++)[4]	(-)	25-130 (-)	100-600 (-)
2	Arsenic; white arsenic	Arsenic trioxide	As_2O_3	197.82	White crystals or amorphous; d = 3.71.	Sublimes	sl.s.w.; s.alk., HCl; carbonates	25-100 (++ to +++)[5]	25-100 (++ to +++)[5]	(-)	(-)
3	Barium carbonate	Barium carbonate	$BaCO_3$	197.37	White rhomboids; d = 4.43.	dec.: 1300	i.w.; s.HCl, HNO_3, NH_4Cl	750-1480 (+)	(-)	(-)	150+ (-)
4	Fumarin	Coumarin, 3-(1'-furyl-2'-acetyl)-ethyl-4-hydroxy-	$C_{17}H_{14}O_5$	298	White powder.	121-123	i.w.; s.org. solv., alk.	5[6] (+++)	5[6] (+++)	5[6] (+++)	
5	Phosphorus, yellow	Yellow phosphorus	P_4	124.08	White or yellowish cubic or waxy solid; d = 1.82.	44.1	i.w.; s.chl., bz., CS_2	1.7 (++)	1.7 (++)	(-)	(-)
6	Pival	1, 3-Indandione, 2-pivalyl-[7]	$C_{14}H_{14}O_3$	230.27	Yellow needles.	108-110	i.w.; s.org. solv., alk.	5[6] (+++)	5[6] (+++)	5[6] (+++)	
7	Red squill[8]				Red powder.		Sl.s.w., acet., chl.; gluco-side extr. by al.	400-600 (++)[9]	(-)	(-)	(-)
8	Sodium fluoroacetate; compound 1080	Fluoacetic acid, sodium salt	FCH_2COONa	100.01	White powder.	dec.: 201-204	s.w.	2-5 (+++)	2 (+++)	10 (+++)	1.4-2.2 (+++)
9	Strychnine	Strychnine	$C_{21}H_{22}N_2O_2$	334.40	Rhombic crystals from al.	268-290	i.w.; s.chl.	16 (-)	(-)	6 (++)	(++)
10	Strychnine sulfate	Strychnine sulfate	$(C_{21}H_{22}N_2O_2)_2$ $H_2SO_4 \cdot 5H_2O$	856.97	Colorless monoclinic crystals.	dec.: 200	sl.s.2., al.; l.eth.; s.gly.	4.8 (-)	8 (-)	8 (++)	(++)
11	Thallium sulfate	Thallium or thallous sulfate	Tl_2SO_4	504.84	White rhombic crystals; d = 6.77.	632	al.s.s.w.; s.h.w.	16-25 (+++)	25 (+++)	25 (+++)	
12	Warfarin	Coumarin, 3-(a-acetonylbenzyl)-4-hydroxy-[7]	$C_{19}H_{16}O_4$	308.32	Colorless needles from al.	159-161	i.w.; s.al., acet., alk.	50 (+++)	5-20[6] (+++)	5-10[6] (+++)	
13	Zinc phosphide	Zinc phosphide	Zn_3P_2	258.11	Dark gray cubic crystals; d = 4.55	420+	i.w.; dec. with evolution of PH_3 in acids.	40 (++)	40 (++)	40 (++)	(++)

	Common Name	Physiological Effects			Rate of Action	Relation to Man and Other Animals			
		Cumulation (Fatal)	Tolerance Developed	Cause of Death		Secondary Poisoning	Skin Absorption	Hazard in Use	Antidote[10]
1	ANTU	No	Yes	Pulmonary edema; pleural effusion.	Slow.	No	No	Moderate	None.
2	Arsenic; white arsenic	No	Yes	Kidney damage; gastroenteritis; CNS affected.	Slow	No	No[11]	Moderate	Milk of magnesia, milk and H_2O, oxide of iron.
3	Barium carbonate	No	No	Intestinal spasm; digitalis-like action; CNS paralysis.	Slow.	No	No	Slight	Magnesium sulfate.
4	Fumarin	Yes	No	Blood loss from internal or external hemorrhage.	Very slow, 5-10 days exposure required.	No	No	Slight	Vitamin K, blood transfusions.
5	Phosphorus, yellow	No	No	Heart paralysis; liver and gastrointestinal damage.	Fast.	No	No	Moderate	Copper sulfate, followed with lavage or emetic; cathartic and water; avoid fats and oils.
6	Pival	Yes	No	Blood loss from internal or external hemorrhage.	Very slow, 5-10 days exposure required.	No	No	Slight	Vitamin K, blood transfusions.
7	Red squill[8]	No	No	Heart and respiratory paralysis.	Slow.	No	No	Slight	Acts as emetic in animals capable of vomiting. Treat as for digitalis poisoning.
8	Sodium fluoroacetate; compound 1080	No	No	Heart and CNS paralysis.	Fast.	Yes	No[11]	Extreme	None reliable; monacetin or ethyl alcohol and acetic acid recommended. Rapid i.m. injection of atropine salts (3 mg) effective.
9	Strychnine								No emetic after 10 min, or after onset of convulsions; sedative, charcoal in H_2O, orally.
10	Strychnine sulfate	No	No	Convulsions from hyperstimulation; asphyxia.	Very fast.	No	No	Moderate	
11	Thallium sulfate	Yes	No	Gastrointestinal hemorrhage; kidney and endocrine damage; respiratory failure.	Slow.	Yes	Yes	Extreme	None reliable; sodium iodide and sodium thiosulfate may help.
12	Warfarin	Yes	No	Internal and external hemorrhage.	Very slow; 5-10 days exposure required.	See Fn 12	No	Slight	Vitamin K, blood transfusions.
13	Zinc phosphide	No	No	Heart paralysis; gastrointestinal and liver damage.	Fast.	No	No	Moderate	Copper sulfate, followed with lavage or emetic; cathartic and water; avoid fats and oils.

/1/ Abbreviations: acet. = acetone; al. = alcohol; alk. = alkali; bz. = benzene; c. = cold; chl. = chloroform; dec. = decomposes; eth. = ether; gly. = glycerine; h. = hot; i. = insoluble; org. solv. = organic solvents; s. = soluble; sl. s. = slightly soluble; w. = water. /2/ Amount necessary to control rodents under conditions of use. /3/ (-) = ineffective; (+) = poor; (++) = fair; (+++) = good. /4/ On first exposure only; ingestion of sub-lethal doses results in increased tolerance and decreased effectiveness. /5/ Lethal dose and relative effectiveness vary with particle size. /6/ Successive doses of 1 mg/kg/da required for 5 or more days. Minimum lethal dose (acute oral toxicity): fumarin 400 mg/kg; pival 200-250 mg/kg; warfarin 160 mg/kg. /7/ Alkaline salts available for use in aqueous solutions. /8/ Crude drug consists of powdered inner scales of Urgines maritima, with or without fortification of alcoholic extracts. Active principle appears to be one or more glucosides, one of which (scilliroside) has the formula $C_{32}H_{44}O_{12}$. /9/ Toxicity of crude drug may be increased through addition of alcoholic extractives, such as scilliroside. /10/ Emetics are used as first aid, except as noted. One tablespoon of salt in warm water is usually effective; physician should be called immediately. /11/ May be absorbed through cuts or breaks in the skin, also by inhalation of dusts. /12/ Reported poisonings from ingestion of warfarin-poisoned animals.

	Common Name	Chemical Definition	Action
		Inorganic	
1	Borax	Sodium tetraborate, $Na_2B_4O_7 \cdot 10H_2O$.	Probably slow nerve poison.
2	Calcium arsenate	Mixture of $CaHAsO_4$, $Ca_5H_2(AsO_4)_4$, $Ca_3(AsO_4)_2$, $[Ca_3(AsO_4)_2]_3Ca(OH)_2$, free $CaCO_3$ and unreacted $Ca(OH)_2$.	Destroys mid-gut epithelium.
3	Calomel	Mercurous chloride, $HgCl$.	Enzyme inhibitor.
4	Corrosive sublimate	Mercuric chloride, $HgCl_2$.	Enzyme inhibitor.
5	Cryolite	Sodium aluminum fluoride, Na_3AlF_6.	Produces flaccid paralysis.
6	Lead arsenate	Acid lead arsenate, $PbHAsO_4$.	Destroys mid-gut epithelium.
7	Paris green	Copper acetoarsenite, $(CuOAs_2O_3) \cdot Cu(CH_3COO)_2$.	Inhibits enzymes with sulfhydryl groups.
8	Sodium arsenite	Mixture of Na_3AsO_3 and $NaAsO_2$.	Destroys mid-gut epithelium.
9	Sodium fluoride	Sodium fluoride, NaF.	Nerve, stomach poison.
10	Sodium fluosilicate	Sodium silicofluoride, Na_2SiF_6.	Nerve, stomach poison.
11	Sodium selenate	Sodium selenate, Na_2SeO_4.	Similar to H_2S; blocks cytochrome system(?).
12	Tartar emetic	Potassium antimonyl tartrate $K(SbO)C_4H_4O_6 \cdot 1/2H_2O$.	Similar to arsenic poisoning.
13	White arsenic	Arsenious oxide, As_2O_3.	Destroys mid-gut epithelium.
		Organic	
14	Aldrin	Not less than 95% of 1, 2, 3, 4, 10, 10 -hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene.	Delayed action on nerve.
15	Allethrin	dl-2-Allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one ester of cis- and trans-dl-chrysanthemum monocarboxylic acid.	Rapid veratrine-like nerve poison.
16	Anabasine	1-3-(2'-Piperidyl)pyridine.	Rapid nicotinic nerve poison.
17	BHC	A mixture of several isomers of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane.	Potent stomach poison and persistent contact poison; fumigant.
18	Chlordane	1, 2, 4, 5, 6, 7, 8, 8-Octachloro-2, 3, 3a, 4, 7, 7a-hexahydro-4, 7-methanoindene.	Delayed action on nerve.
19	Chlorthion	O, O-Dimethyl-O-(3-chloro-4-nitrophenyl) thiophosphate.	Probably anticholinesterase.
20	DDD	2, 2-bis-(p-Chlorophenyl)-1, 1-dichloroethane.	Repetitive nerve discharge.
21	DDT	2, 2-bis-(p-Chlorophenyl)-1, 1-trichloroethane.	Repetitive nerve discharge.
22	Diazinon	O, O-Diethyl-O-(2-isopropyl-4-methyl-6-pyrimidyl)thiophosphate.	Anticholinesterase (technical grade).
23	Dieldrin	Not less than 85% of 1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene.	Delayed action on nerve.
24	Dilan	53% 2-Nitro-1, 1-bis(p-chlorophenyl) butane and 27% 2-nitro-1, 1-bis (p-chlorophenyl) propane, and 20% related compounds.	Probably similar to DDT.
25	DNBP	4, 6-Dinitro-2-butylphenol.	Mordant stimulant nerve poison.
26	DNCHP	2, 4-Dinitro-6-cyclohexylphenol.	Mordant stimulant nerve poison.
27	DNOC	4, 6-Dinitro-o-cresol.	Mordant stimulant nerve poison.
28	Endrin	1, 2, 3, 4, 10, 10-Hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-endo-5, 8-dimethanonaphthalene.	Probably like its isomer, dieldrin.
29	EPN	Ethyl-p-nitrophenylthionobenzenephosphonate.	Impure samples have anticholinesterase activity.
30	Heptachlor	1(or 3a), 4, 5, 6, 7, 8, 8-Heptachloro-3a, 4, 7, 7a-tetrahydro-4, 7-methanoindene.	Delayed action on nerve.
31	Isodrin	1, 2, 3, 4, 10, 10-Hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4-endo-endo-5, 8-dimethanonaphthalene.	Delayed action on nerve, like aldrin.
32	Isopestox	bis-(Isopropylamino)fluophospine oxide.	Eventual anticholinesterase effect.
33	Lethane 60	Mixture of β-thiocyano ethyl esters of aliphatic fatty acids; av. C content is 10-18; $(CnH_{2n-1}COOCH_2CH_2SCN)$, with 50% petroleum distillate.	Depression of respiration, rapid knockdown.
34	Lethane 384	Mixture of β-butoxy-β-thiocyanodiethyl ether with 50% petroleum distillate.	Depression of respiration, rapid knockdown.
35	Lindane	Not less than 99% of gamma isomer of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane.	Rapid nerve stimulant.
36	Malathion	O, O-Dimethyl-S-(1, 2-dicarbethoxyethyl) dithiophosphate.	Anticholinesterase enzyme inhibitor.
37	Methoxychlor	1, 1, 1-Trichloro-2, 2-bis (p-methoxyphenyl)-ethane.	DDT-like action on nerve.
38	Methyl-parathion	O, O-Dimethyl-O-p-nitrophenyl thiophosphate.	Anticholinesterase.
39	Nicotine	1-3-(1-Methyl-2-pyrrolidyl)-pyridine.	Blocks ganglionic synapses.
40	Parathion	O, O-Diethyl-O-p-nitrophenyl thiophosphate.	Anticholinesterase.
41	PDB	p-Dichlorobenzene.	Stimulant, probably nervous.
42	PCP	Pentachlorophenol.	Repellent and fumigant.
43	Perthane	1, 1-bis-(p-Ethylphenyl)-2, 2-dichloroethane.	Probably similar to DDT.
44	Phenothiazine	Dibenzo-1, 4-thiazine, thiodiphenylamine.	Slow flaccid paralysis.
45	Pyrolan	Dimethyl-5-(3-methyl-1-phenyl-pyrazolyl)carbamate.	Anticholinesterase.
46	Pyrethrins	Pyrethrolone and cinerolone esters of chrysanthemum monocarboxylic acid and chrysanthemum dicarboxylic acid methyl ester.	Rapid veratrine-like nerve poison.
47	Rotenone	$C_{23}H_{22}O_6$.	Depresses respiration and nerve.
48	Ryania	Powdered stems of R. speciosa, containing active principle ryanodine $(C_{25}H_{35}O_8N)$.	Ryanodine depresses muscle metabolism.
49	Sabadilla	Powdered seeds of sabadilla (Schoenocaulon spp), containing veratrine and veratridine.	Mild veratrine-like poison.
50	Schradan	Octamethylpyrophosphoramide.	Converted in vivo to anticholinesterase.
51	Strobane	Mixture of terpene polychlorinates containing about 66% chlorine.	Probably similar to Schradan.
52	Systox	Mixture of O, O-diethyl-S-ethylmercaptoethyl thiophosphate and O, O-diethyl-O-ethylmercaptoethyl thiophosphate.	Anticholinesterase.
53	TEPP	Tetraethyl pyrophosphate, $(C_2H_5O)_2PO \cdot O \cdot PO(OC_2H_5)_2$.	Quick knockdown; synergist.
54	Thanite	Isobornyl thiocyanoacetate, plus 18% terpene esters.	Delayed action on nerve.
55	Toxaphene	Mixture of chlorinated camphene isomers containing 67-69% chlorine.	

/1/ Oral, principally to albino rats, milligrams per kilgram body weight. /2/ Also Blattella germanica. /3/ Also Boophilus microplus, Sclerosarcus cacciali, Rhopobota naevana, Drosophila. /6/ Also Chromaphis juglamdicola.

Method	Insects Especially Affected	Insects Developing Tolerance	Rats LD_{50}[1] mg/kg	
	Inorganic			
Powders or aqueous solutions.	Housefly and blowfly maggot,			1
Crop and forest dusting.	Corn earworm, cotton leafworm.		50	2
Seed or seedling treatment.	Root maggot.		1-5	3
Seed or seedling treatment.	Root maggot.		1-5	4
Orchard and crop sprays and dusts.	Codling-moth, velvet bean caterpillar.	Rhagoletis completa.		5
Orchard sprays and dusts.	Codling-moth, peach moth.	Carpocapsa, Anarsia.	100	6
Sprays, dusts, baits.	Potato beetle, anopheline larva, cutworm.			7
Livestock dips, baits.	Cutworm, grasshopper.	Boophilus decoloratus, australis.	200	8
Dry powders.	Cockroach, ant, Mallophaga.		200	9
Baits, powders, impregnants.	Grasshopper, ant, clothes moth.		150	10
Systemic, by watering soil.	Aphids, scale, thrips.	Tetranychus telarius.	5	11
Bait sprays, ant traps.	Thrips, caterpillar, ant.	Scirtothrips, Taeniothrips.	6	12
Ant traps, grasshopper baits.	Ant, grasshopper.		2-85	13
	Organic			
Baits, sprays, soil treatments.	Grasshopper, wireworm, ant, cutworm, root maggot, white grub.	Aedes, Culex, Musca.	50	14
Domestic aerosols, louse powders.	Housefly, louse, livestock insects.		1000	15
Contact and fumigant sprays.	Aphids.		10	16
Wettable powder, dispersible liquid or dust.	Field and garden insects, wireworm.	Musca, Boophilus decoloratus, B. microplus, Cimex, Drosophila.[2]	1200	17
Dusts and residual sprays.	Cockroach, ant, mosquito, plum curculio, cotton boll weevil.	Blattella, Musca, Culex tarsalis[3]	500	18
Wettable powder sprays.	Mosquito, housefly, grape berry moth.		1000	19
Orchard sprays.	Leaf-roller, corn earworm.	Musca, Aedes taeniorhynchus[4]	2500	20
Residual sprays and dusts, paints and resin coatings, domestic aerosols.	Caterpillar, sawfly, household insects, louse, cotton boll weevil, grasshopper, Mexican bean beetle; virtually all insects except resistant species.	Musca, Aedes, Culex, Pediculus, Psychoda, Cimex, Anopheles, Carpocapsa, Boophilus, Pieris, Leptinotarsa(?), Pulex, Plutella, Blatta, Tristoma.[5]	250	21
Wettable powder sprays.	Orchard insects, housefly.		100	22
Residual sprays.	Housefly, mosquito, ant, assassin bug, plum curculio, chinch bug, flea beetle.	Musca, Psychoda, Aedes nigromaculis, Boophilus microplus.	65-100	23
Residual emulsion sprays.	Housefly, Mexican bean beetle.	Musca.	1100	24
Dormant orchard sprays.	Aphid eggs, overwintering forms.		5-60	25
Summer orchard sprays.	Orchard mites.		30-180	26
Contact sprays and dusts.	Grasshopper, aphid eggs.		45	27
Baits and residual sprays.	Grasshopper, tobacco insects.		10	28
Orchard suspension sprays.	Aphids, psyllids, plum curculio, mosquito larva.		15-90	29
Dusts, wettable powder and emulsion sprays.	Cockroach, plum curculio, blackfly larva, cotton mite, cutworm, rootworm, wireworm.	Culex, Aedes nigromaculis	200	30
Baits and residual sprays.	Bark beetle, cutworm.		15	31
Systemic foliage sprays.	Aphids.		90	32
Aerosols and emulsion sprays.	Housefly, louse, livestock insects.		500	33
Aerosols and emulsion sprays.	Housefly, louse, livestock insects.		400	34
Contact and residual sprays, electric vaporizers, dusts.	Housefly, mosquito, louse, wireworm, household stored-products insects, orchard and field crop insects.	Musca, Blattella, Pediculus, Anopheles, Boophilus	125	35
Residual and orchard sprays, baits.	Aphids, scale, orchard mites, housefly, mosquito larva.		1250	36
Residual and livestock sprays.	Forage and truck-crop insects, Mexican bean beetle.	Musca, Pieris rapae, Drosophila.	6000+	37
Orchard sprays.	Aphids.			38
Contact sprays, fumigant vapors.	Aphids, psyllids.		10	39
Contact and residual sprays.	Aphids, most insects.	Tetranychus, Metatetranychus.[6]	3.5	40
Fumigant of soil and closed spaces.	Clothes moth, peach borer.		2000	41
Wood impregnant.	Powder-post beetle, termite.		210	42
Wettable powder, emulsion sprays.	Leafhopper nymph, forage-crop insects.		8000	43
Oral anthelmintic.	Bot and mosquito larva.	Callitroga americana (lab.).	1500+	44
Surface sprays.	Woolly apple aphid, housefly.		60-90	45
Domestic aerosols, sprays, dusts.	Housefly, mosquito, louse, truck-crop insects, livestock insects.	Musca, Blattella.	1500	46
Crop dusts, livestock sprays.	Caterpillar, sheep-ked.	Epilachna varivestis.	25-1000	47
Dusts or wettable powders.	European corn borer, codling moth.		1200	48
Dusts.	Leafhopper, squash bug.		2000+	49
Systemic application to plants.	Aphids, scale.		20	50
Liquid insecticide.	Acarids.		250	51
Systemic application to plants.	Cotton aphid.			52
Rapid contact sprays.	Aphids, scale.	Tetranychus.	2	53
Livestock sprays and aerosols.	Housefly, horn-fly, stable-fly.		1000	54
Residual sprays and dusts.	Cotton boll weevil, cutworm, grasshopper, salt-marsh caterpillar.	Musca, Culex.	60	55

Anopheles, Psychoda. /4/ Also A. sollicitans, Pieris rapae, Drosophila. /5/ Also Erythroneura variabilis, Trichoplusia Ni., Lygus bugs, Psychoda,

350. REPRESENTATIVE ARTHROPOD REPELLENTS: CHARACTERISTICS AND EFFECTIVENESS

Values in parentheses are ranges.

	Chemical Designation	Empirical Formula	Physical Properties[1,2]	Solubility[1]	Anopheles quadrimaculatus		Aedes aegypti		Amblyomma americanum	Ctenocephalides felis	Trombiculid (Chigger) Mites	
					Min to 1st Bite, Skin[3]	Da to 5th Bite, Cloth[3]	Min to 1st Bite, Skin[3]	Da to 5th Bite, Cloth[3]	Da Effective on Cloth[3]		Min to 100% Knockdown[3]	Effective after Washes no.[3]
1	Benzyl benzoate (benzoic acid, benzyl ester)	$C_{14}H_{12}O_2$	MW=212.24; needles, leaflets or clear oily liq.; MP=21; BP=323.4; den. $=1.14^{18}$; sp gr $=1.1414$; $n_D=1.5681_{25}$	i.w.;s.acet., al., eth.	23(2-97)	<1	99(2-347)	0-5	103	197	1	3
2	Butyl acetanilide (N-butylacetanilide)	$C_{13}H_{17}ON$	MW=203.27; clear liq., colorl. to light straw; MP (setting point)=22; BP=277-281; sp gr=0.99$^{25}_{25}$	i.w.;s.acet., al., eth.	116(14-374)	6	218(39-481)	8-36	54-139	29	0.5	2
3	2-Butyl-2-ethyl-1, 3-propanediol(1, 3-propanediol, 2-butyl-2-ethyl)	$C_9H_{20}O_2$	MW=160.25; wh. cr.; MP=41.4; BP=178^{50}; den.=0.924^{60}	0.8% s.w. at 20°C;s.acet., al., eth.	18(11-25)	<1	63(21-104)	93-196	27	<1	15+	
4	N-sec.-Butylphthalimide (phthalimide, N-sec.-butyl)[4]	$C_{12}H_{13}O_2N$	MW=203.23; clear liq.; BP=114-116$^{3}_{3}$; sp gr=1.1122^{26}	i.w.;s.acet., al., eth.	55(11-122)		198(11-511)	14	12	14	0.5	0
5	o-Chloro-N,N-diethylbenzamide (benzamide, o-chloro-N,N-diethyl)	$C_{11}H_{14}ONCl$	MW=211.69; colorl. prisms; MP=39-40; BP=125-128	i.w.;s.acet., al., eth.			470+(404-5124)	1-28	8	84	1.5	0
6	Citronella, Ceylon (oils, citronella, Ceylon)[4]		Pale, yel. liq.; sp gr=0.92$^{16}_{4}$; n_D=1.479-1.485$_{20}$	sl.s.w.;10 vol. 80% al.	15(7-19)		74(30-148)	20-27	8		0.5	0
7	Citronella, Java (oils, citronella, Java)[4]		Pale, yel. liq.; den. =0.885-0.900; n_D=1.468-1.473$_{20}$	sl.s.w., 10 vol. 80% al.	26(10-41)		114(91-157)				15+	
8	Cyclohexyl acetoacetate (acetoacetic acid, cyclohexyl ester)[4]	$C_{10}H_{16}O_3$	MW=184.23;colorl. liq.; BP=81-83$^{0.3}_{3}$; sp gr=1.021$^{25}_{25}$; n_D=1.4590$_{20}$	i.w.;s.acet., al., eth.	57(15-226)		109(15-275)	5			15+	
9	Dibutyl adipate (adipic acid, dibutyl ester)	$C_{14}H_{26}O_4$	MW=258.35; colorl. liq.; MP=-38; BP=183$^{15}_{15}$; sp gr=0.965$^{20/4}$	i.w.;misc.al., eth.	21(1-61)		36(12-66)	<1	49	<1	2	3
10	Dibutyl phthalate (phthalic acid, dibutyl ester)	$C_{16}H_{22}O_4$	MW=278.34; oily, colorl. liq.; BP=340; sp gr=1.045$^{25}_{4}$	0.04%s.w.; v.s.al., eth., acet., ba.	18(2-84)		12(1-86)	160			12.5	3
11	Diethyl cyclohexanedicarboxylate (1,2-cyclohexane dicarboxylic acid, diethyl ester)[4]	$C_{12}H_{20}O_4$	MW=228.28; liq.; BP=83-87$^{0.5}$; n_D=1.453$_{25}$	i.w., s.acet., al., eth.	57(15-176)		176(16-369)	27+	5		1	0
12	N,N-Diethyl-m-toluamide (tech.) (m-toluamide, N,N-diethyl)	$C_{12}H_{17}ON$	MW=191.26; colorl. liq.; BP=111$^{1}_{1}$; sp gr=0.9965^{25}; n_D=1.5206$_{25}$	i.w.;s.acet., al., eth.			812(706-840)	11-63	54	30-56[5]	0.2	0
13	Dilsopropyl tartrate (tartaric acid, diisopropyl ester)[4]	$C_{10}H_{18}O_6$	MW=234.24; colorl. oily liq.; BP=275; sp gr=1.1171^{25}; n_D=1.4379$_{25}$	i.w.;s.acet., al., eth.	40(8-94)		255(7-499)	1			5.5	0
14	Dimethyl carbate (Bicyclo[2, 2, 1]-5-heptene-2, 3-dicarboxylic acid, cis-, dimethyl ester)[4]	$C_{11}H_{14}O_4$	MW=210.22; cr. solid; MP=>35 (setting point); sp gr=1.162-1.167$^{25/4}$	i. w.;misc. al.	66(9-270)	20	229(28-456)	21+	19		0.5-2.5	0
15	Dimethyl phthalate (phthalic acid, dimethyl ester)[4]	$C_{10}H_{10}O_4$	MW=194.18; clear, oily liq.; BP=282; sp gr=1.190-1.194; n_D=1.5154$_{21}$	0.43% s.w.; s.acet., al., eth.	108(5-542+)	4-21+	247(5-1051)	11-27			1-2	0
16	2-Ethoxy-N, N-diethylbenzamide (benzamide, 2-athoxy-N, N-diethyl)	$C_{13}H_{19}O_2N$	MW=221.29; liq.; BP=115$^{0.1}$; sp gr = 1.0294^{25}; n_D=1.5159$_{25}$	i.w.,s.acet., al., eth.			366(250-496)	16-63	15	92[5]	1.5	0
17	2-Ethyl-1, 3-hexanediol (1, 3-hexane-diol, 2-ethyl)[4]	$C_8H_{18}O_2$	MW=146.22; clear oily liq.; BP=244, 2; sp gr=0.942^{20}; n_D=1.4465-1.4515$_{25}$	4.2% s.w.;s. hydrocarb.	53(2-312)	0-3	331(12-608)	27			3.5-10.5	0
18	Ethyl-β-phenyl hydracrylate (hydracrylic acid, β-phanyl-ester)[4]	$C_{11}H_{14}O_3$	MW=194.22; oily liq.; BP=124-125^{1}; sp gr=1.090^{15}; n_D=1.5082$_{22}$	i.w.;s.acet., al., eth.	42(19-73)		262(33-497)	36	119		0.5	0
19	Haxyl mandelate (mandelic acid, hexyl ester)	$C_{14}H_{20}O_3$	MW=226.30; liq.; BP=136^{3}; sp gr= 1.026^{25}; n_D=1.4910$_{25}$	i.w.;s.acet., al., eth.	80(49-165)		279(49-502)	154	83	28	2	0
20	Indalone (2H-pyran-6-carboxylic acid, 3, 6-dihydro-2, 2-dimethyi-4-oxo-butyl ester)[4]	$C_{12}H_{18}O_4$	MW=226.26; light yel. liq.; BP=256-70; sp gr=1.058-1.062; n_D=1.4745-1.4755$_{25}$	i.w.;misc.al., chl., eth., glac.ac.a.	41(3-186)		141(24-411)	0-161	32	1	0.5-2	0
21	Navy 448 ingredients (2-cyclohexylcyclohexanol (cyclohexanol, 2-cyclohexyl)	$C_{12}H_{22}O$	MW=182.30; visc. liq.; BP=125-128^{7}; sp gr=0.9750^{20}	v.sl.s.w.;s. acet.,al., eth.	44(1-115)		304(2-615)	18	29		0.5	0
22		$C_{12}H_{16}O$	MW=176.25; light amber liq.; sp gr= 1.0450^{26}	v.sl.s.w.;s. acet.,sl., eth.	76(1-382)	1-4	368(3-1354)	27	14		0.5	0

23	Navy 448 (mixture of 30% 2-cyclo-hexylcyclohexanol and 70% phenylcyclohexanol)							282	18	13	8-22		
24	1, 5-Pentanediol, dipropionate (propionic acid, diester with 1, 5-pentanediol)[4]	$C_{11}H_{20}O_4$	MW=216, 27; clear, colorl. liq.; BP=110[2, sp gr=0.9910[25]; n_D=1.4274$_{25}$	i.w.;s.acet., al., eth.	89(21-281)		160(30-304)				1-2		
25	2-Phenoxyethanol, acetate (ethanol, 2-phenoxy-, acetate)[4]	$C_{10}H_{12}O_3$	MW=180, 20; liq.; BP=147-150[23]; sp gr=1.1000[25]; n_D=1.505821	l.w.;s.acet., al., eth.	53(6-212)		164(10-363)	8-20			0, 5	0	
26	Propylcinnimate (cinnamic acid; propyl ester)[4]	$C_{12}H_{14}O_2$	MW=190, 23; liq.; BP=122[1 n_D =1.5467$_{28}$										
27	Propyl N, N-diethyl succinnamate (succinnamic acid, N, N-diethyl-, propyl ester)[4]	$C_{11}H_{21}O_3N$	MW=215, 29; clear liq.; BP=107-108[0.5, sp gr=1.006-1.011; n_D=1.4517$_{22}$	l.w.;s.acet., al., eth.	61(8-273)		322(16-494)	38	28	<1	1, 5	0	
28	Thiodiethanol, diacetate (ethanol, 2, 2'-thiodi-, diacetate)[4]	$C_8H_{14}O_4S$	MW=206, 26; colorl. liq.; BP=130[2; sp gr=1.1380[25]; n_D=1.468425	l.w.;s.acet., al., eth.	47(14-328)		237(40-362)	0-63			2, 5	0	
29	Undecenoic acid (undecylenic acid)	$C_{11}H_{20}O_2$	MW=184, 27; liq. or cr.; MP=24, 5; BP=275 d.; den. =0.9102; n_D=1.4464$_{24}$	l.w.;s.al., chl., eth.	128(8-277)	<1	168(83-460)	19+	21-123	133	2-5	0	

/1/ Abbreviations and symbols: ac.a. = acetic acid; acet. = acetone; al. = alcohol; BP = boiling point; bz. = benzene; chl. = chloroform; colorl. = colorless; cr. = crystals, crystalline; d. = decomposes; den. = density; eth. = ether; glac. = glacial; hydrocarb. = hydrocarbon; i. = insoluble; liq. = liquid; MP = melting point; misc. = miscible; MW = molecular weight; n_D = refractive index; s. = soluble; sl. = slightly; sp gr = specific gravity; v. = very; w. = water; wh. = white; yel. = yellow; visc. = viscous. /2/ MP in °C; BP in °C at atmospheric pressure (760 mm of mercury) unless otherwise indicated by specific pressure in underlined superscript; sp gr and den. at temperature (°C) indicated by underlined superscript, except in Lines 9 and 14, where temperature is referred to water at 4°C; refractive index (n_D) at temperature of °C shown in subscript. /3/ For techniques, see U.S. Department of Agriculture Handbook No. 69, "Chemicals Evaluated as Insecticides and Repellents at Orlando, Fla.," U. S. Government Printing Office, May 1954. /4/ Deemed safe for use on skin. /5/ Tests conducted with oriental rat flea (Xenopsyll cheopis).

351. ORGANIC INSECTICIDES: LARVICIDAL, KNOCKDOWN, AND LD_{50} TESTS

	Insecticide	Larvicide Test Results[1]			Knockdown Test Results[2]				Insecticide	Larvicide Test Results[1]			Knockdown Test Results[2]			
		100% Effective Dose[3]	Lower Doses		100% Knockdown	100% Effective for:[4]	Topical LD_{50}[5]			100% Effective Dose[3]	Lower Doses		100% Knockdown	100% Effective for:[4]	Topical LD_{50}[5]	
		ppm	ppm	% kill	hr	da	µg/g			ppm	ppm	% kill	hr	da	µg/g	
1	Aldrin	0.025	0.01	98	1	31+	1.6	21	Methyl parathion	0.005	0.0025	67	0.25	31+	1.0	
2	Allethrin	0.2	0.1	76	1	31+	21.5	22	Nicotine		10.0	15				
3	BHC	0.2	0.1	92	0.25	30-31		23	Para-oxon	0.025	0.01	82		31+	0.5	
4	Chlordane	0.01	0.005	52	3	31+	4.0	24	Parathion	0.0025	0.001	80	0.25	31+	0.9	
5	DDT	0.01	0.005	66	6	31+	1.65	25	PDB		10.0	70	24+	0		
6	DFDT	0.025	0.01	85	6	31+	5.0	26	Pentachloro-phenol	10.0	1.0	45	1	30-31		
7	Dieldrin	0.005	0.0025	90	3	31+	1.1	27	Phenothiazine	1.0	0.1	5	24+	0		
8	Dilan	0.1	0.05	94	24	7-8	4.75	28	Potasan	0.1	0.01	18	0.5	31+		
9	DNOC	10.0	1.0	10	1	31+		29	Pyrolan		10.0	98	1	31+		
10	DNOCHP	10.0	1.0	50	3	31+		30	Pyrethrins	0.1	0.05	78	0.25	30-31	1.0	
11	DNOSBP	10.0	1.0	0	0.25	30-31		31	Rotenone	10.0	1.0	60	24+	0		
12	Endrin		0.01	96	1	31+		32	Sabadilla				3	31+		
13	EPN	0.005	0.0025	96	24	31+	1.9	33	Schradan		10.0	42	6	31+	>500	
14	Heptachlor	0.025	0.01	79		31+	1.6	34	Sulfotepp	0.0025	0.001	74	0.5	31+	5.0	
15	Isodrin	1.0	0.1	78	3	31+		35	Systox	0.1	0.01	6	0.25	31+		
16	Lethane 60[6]		10.0	20	0.5	16		36	TDE	0.005	0.0025	95	6-24	0-1	0.5	
17	Lethane 384[6]		10.0	20	1	31+	120	37	TEPP	10.0	1.0	42	1	3-7		
18	Lindane	0.05	0.025	62	0.5	31+	1.0	38	Thanite	10.0	1.0	5	3	31+	150	
19	Malathion		0.025	96	1	31+	28	39	Toxaphene	0.01	0.005	80		31+	31.0	
20	Methoxychlor	0.1	0.05	45	24+	0	3.4									

/1/ Fourth-instar larvae (Anopheles quadrimaculatus) exposed 48 hr in serial water-dilutions of test compound-acetone solution. /2/ Young adults (Pediculus humanis corporis) exposed 24 hr on dry woolen patches previously dipped in 1% solutions of insecticides in solvent. /3/ A measure of minimum lethal concentration. /4/ A measure of residual effectiveness. /5/ Musca domestica. /6/ Data on per cent active ingredients not available.

	Common Name	Chemical Formula or Designation	MP °C[1]	BP °C[1]	Form, Color, Solubility[1]	Organisms Susceptible in Vitro[1,2,3]	Indications	Toxicity and Remarks
1	Benzoic acid	Benzene carboxylic acid.	122	249	Colorl. crys.; sl.s.w.; s. most org. solv.	Fungistatic. 2-6, 8, 10, 11, 14.	Dermatomycoses.	Used in combination with salicylic acid. Should not be used in acute phase.
2	Boric acid	H_3BO_3	160	300 (-1½ H_2O)	Colorl. crys. or white granules or powder; s. w., sl., gly.; sl.s.aet.	Fungistatic. 1, 2, 4-6, 9-11.	Tinea pedis, T. cruris.	Should not be used over extensive areas of unbroken skin. Poisoning from topical use has occured in infants.
3	Caprylic acid	$CH_3(CH_2)_6COOH$	16	237	Colorl. liq.; sl.s.w.; s.al., eth., eth., CS_2, pet.eth., glac.ac.s.	Fungistatic, weakly fungicidal. 1, 2, 4-6, 9-14.	Dermatomycoses.	Relatively non-toxic on local application. Unpleasant odor. Only suppressive efficacy.
4	Chloramphenicol	d-(-)-Threo-1-p-nitrophenyl-2-dichloroacetamido-1, 3-propanediol.	150.5-151.5		Needles; sl.s.w.; s.al., acet., eth., ethyl acetate, me.alc., butyl alc., prop. glycol.	A, E, G.	Actinomycosis, cryptococcosis, nocardiosis.	Occasional blood dyscrasias. May cause candidiasis.
5	5-Chloro-salicylanilide	$C_{13}H_{10}O_2NCl$	214-216		Crys.; i.w.; sl.s.al., gly.; s.acet.	Fungistatic, weakly fungicidal. 2, 4-6, 9, 10, 12.	Tinea capitis.	About 75% effective. Occasional dermatitis, folliculitis and kerion.
6	Chlorothymol	6-Chloro-4-isopropyl-1-methyl-3-phenol.	62-64		Crys.; sl.s.w.; s.al., bz., chl., eth., pet.eth.	Fungistatic, fungicidal. 2, 9-12, 14.	Tinea pedis.	Primary skin irritant. Effectivity reduced in presence of serum.
7	Chlortetracycline	$C_{22}H_{23}ClN_2O_8$	168-169		Yellow crys.; sl.s.w., alcohols, acet., bz.; s. cellosolves, dioxane, carbitol.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis may result.
8	Diamthazole dihydrochloride	2-Dimethylamino-6-(β-diethylaminoethoxy)-benzothiazole dihydrochloride.	249		Colorl. crys.; s.w., al., me.alc.	Fungistatic, weakly fungicidal. 1, 2, 4-6, 9-12, 14.	Dermatomycoses.	Reported to cause encephalopathy in children under 5 years. Not to be used in acute stage.
9	Dibrom-salicylaldehyde	3, 5-Dibromo-2-hydroxybenzaldehyde.	86		Yellow prisms; sl.s.w.; s.eth., bz., chl., al., glac.ac.s.	Fungistatic, weakly fungicidal. 2, 4-6, 9-12, 14.	Tinea capitis.	20% effective. Occasional dermatitis, folliculitis, and kerion.
10	Ethyl vanillate	3-Methoxyethyl benzoate.	44	291-293	Colorl. crys. solid; i.w.; s. al., sp. glycol, carbowax, mod. conc. cold KOH.	D, F.	Coccidioidomycosis, histoplasmosis.	Low toxicity. 30-45 g/da for 3-18 mo produces occasional nausea, acidosis, hyperpnea, or shock. Liver and kidney damage from larger doses after a month or more.
11	Gentian violet	Methylrosaniline chloride.			Green powder; s.w., al., gly., chl.; i.eth.	Fungistatic. C, 1, 2, 4-6, 9, 10, 12, 14.	Candidiasis, Tinea corporis, T. cruris.	Usually non-toxic topically. Stains skin and clothing. Orally may cause nausea, vomiting, diarrhea, and lassitude.
12	8-Hydroxyquinoline	8-Quinolinol	76	267	White crys.; almost i.w., eth.; s.al., acet., chl., bz.	Fungicidal, fungistatic. 1, 2, 9-13.	Dermatomycoses.	Occasional local allergic-type reaction.
13	Iodine tincture U.S.P.	2% iodine, 2.4% sodium iodide, alcohol.			Transparent, reddish-brown liquid.	Fungistatic. H, 1, 2, 4-6, 9, 10.	Dermatomycoses, superficial lesions in sporotrichosis.	Iodism on chronic use. Not to be used in acute phase topically.
14	Methyl paraben	Methyl parahydroxy-benzoate.	125-128		Colorl. crys.; s. 1/400 w., al., eth.; sl.s.bz., CCl_4.	Fungistatic. C, 1.	Candidiasis.	Mixed with 4 parts propyl paraben to prevent candidiasis from antibiotic therapy. Less toxic than benzoic or salicylic acids.
15	Nystatin	Derived from cultures of Streptomyces noursei.			Yellow powder; sl.s.me. alc., prop. glycol.	Fungicidal. C, 1.	Candidiasis.	LD_{50} for crude nystatin i.p. in mice, 20-26 mg/kg. Too irritating for subcutaneous or intramuscular injection. Combined with antibiotics to prevent candidiasis.
16	Oxytetracycline	$C_{22}H_{24}N_2O_9$	181-182 d.		Yellow crys. or powder; sl.s.w., al.; s.dil. HCl.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis may result.
17	Penicillin G sodium	Benzylpenicillin sodium.			White crys.; s.al., gly.; i.acet., eth., chl.	A, E, G.	Actinomycosis, cryptococcosis, nocardiosis.	Skin rashes and eruptions, serum sickness-like symptoms, anaphylaxis, id-like reactions, mucosal lesions, other systemic reactions in sensitive people. May produce candidiasis.
18	Phenyl mercuric acetate	$C_6H_5HgO_2C_2H_3$	149		White prisms; s.al., bz., 1/600 w.	Fungistatic, fungicidal. 2, 4-6, 9-12, 14.	Dermatomycoses.	Chronic use may produce mercury poisoning. Acrodynia in children from mercury sensitization. BAL helpful as an antagonist.

19	Phenyl mercuric nitrate, N.F.	$C_6H_5HgOH\text{-}C_6H_5HgNO_3$	178-184 d.			White or gray powder; sl. s.w., sl.; mod.s.gly.	See phenyl mercuric acetate.		
20	Potassium iodide solution, N.F.	Saturated potassium iodide.				Clear, colorless solution.	A, B, C, D, E, H.	Actinomycosis (supplemental), candidiasis, coccidioidomycosis, cryptococcosis, N. Amer. blastomycosis.	Iodism in sensitive people. Must check for sensitivity in candidiasis, coccidioidomycosis, and N. Amer. blastomycosis as exacerbations of indolent infections have occurred.
21	Propionic acid	CH_3CH_2COOH		141		Colorl. liq.; misc. w., al., chl., eth.	Fungistatic. 1, 2, 4-6, 9-11, 13, 14.	Dermatomycoses.	Relatively non-toxic on local application. Effect mostly suppressive.
22	Propyl paraben	Propyl parahydroxy-benzoate.	95-98			Color. crys.; s. 1/2000 w., sl., eth., acet.	See Methyl paraben.		
23	Salicylanilide	$C_6H_5NHCOC_6H_4OH$	134-135			White leaflets; sl.s.w.; s. al., eth., chl., bz.	Fungistatic. 2, 4-6, 9-11, 14.	Tinea capitis, T. favosa.	26% effective. Occasional dermatitis, folliculitis, and kerion.
24	Salicylic acid	o-Hydroxybenzoic acid.	157-159	Sub-limes at 20		White crys. or powder; sl. s.w.; s.al., eth., chl.	Fungistatic. 2-6, 8-11, 14.	Dermatomycoses.	Irritating to skin. Keratolytic effect more pronounced than fungistatic. Used in combination with benzoic acid in Whitfield's Ointment, U.S.P.
25	Sodium iodide	NaI	651			White crys.; s.w., al., gly., acet.	See Potassium iodide.		
26	Stilbamidine	4, 4'-Stilbenedicarbox-amidine.	290 d.			White crys.; s.w.; sl. s. me. alc.	B, D, F.	Coccidioidomycosis, histoplasmosis, N. Amer. blastomycosis.	Local irritation, vascular reactions, kidney and liver damage, delayed facial neuropathy from trigeminal lesions.
27	Sulfadiazine	2-Sulfanilamidopyrim-idine.	252-256			White or yellow powder; sl.s.w., al., acet., serum; s.dil.mineral acids, KOH, NaOH, NH_4OH.	A, E, G.	Actinomycosis, nocardiosis.	May cause contact dermatitis, crystalluria, hematuria, drug fever, renal pathology, agranulocytosis, anemia, hepatic necrosis.
28	Tetracycline	$C_{22}H_{24}N_2O_8$	170-173 d.			Yellow crys. or powder; sl.s.w.; s. sl. (1:50), dil. HCl, alk. hydroxide sol.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis.
29	Undecylenic acid	10-Undecenoic acid.	24.5	275 d.		Colorl. liq.; i.w.; s.al., chl., eth.	Fungistatic, weakly fungicidal. 1, 2, 4-6, 9-14.	Dermatomycoses.	Usually well tolerated locally. Effect mostly suppressive.

/1/ ac. a. = acetic acid; acet. = acetone; al. = ethanol; alc. = alcohol; alk. = alkali; bz. = benzene; chl. = chloroform; colorl. = colorless; conc. = concentrated; crys. = crystals; d. = decomposes; eth. = ethyl ether; glac. = glacial; gly. = glycerol; i. = insoluble; i.p. = intraperitoneal; me. = methyl; mod. = moderately; org. solv. = organic solvents; pet. = petroleum; prop. = propylene; s = soluble; sl. = slightly; sol. = solution[s]; w. = water. /2/ Deep mycoses: A = Actinomyces bovis; B = Blastomyces dermatitidis; C = Candida albicans; D = Coccidioides immitis; E = Cryptococcus neoformans; F = Histoplasma capsulatum; G = Nocardia asteroides; H = Sporotrichum schenckii. /3/ Superficial mycoses: 1 = Candida albicans; 2 = Epidermophyton floccosum; 3 = Malassezia furfur; 4 = Microsporum audouini; 5 = M. canis; 6 = M. gypseum; 7 = Nocardia minutissima; 8 = Trichophyton concentricum; 9 = T. mentagrophytes; 10 = T. rubrum; 11 = T. schoenleini; 12 = T. tonsurans; 13 = T. verrucosum; 14 = T. violaceum.

	Common Name	Chemical Name or Formula	Molecular Weight	Melting Point[1] °C	Ferm and Color	Vapor Pressure mm Hg	Purity of Technical Product	Solubility[1] g/100g at 25°C	Toxicity Lethal Dose Rat	Relation to Human Health Skin Absorption	Degree of Hazard
1	Bordeaux mixture	Copper sulfate and lime			Blue gelatinous precipitate; crystallizes on standing.	Non-volatile		i. w.	Slightly toxic.	Poor.	Irritant.[2]
2	Captan; SR-406	N-Trichloromethyl-thio-tetrahydrophthalimide	300. 6	172-173 (pure)[3]	Colorless crys. (pure); yellow amorphous (technical).	Non-volatile		s. w., hydrocarbons; sl. s. al., dioxane, chl.; s. acet., bz.	Oral LD_{50} 10g/kg.	Poor.	Irritant.[4]
3	Captyx	2-Mercaptobenzo-thiazole	167. 2	179	White needles or leaflets.	Low; non-volatile	(?)	<0.005 w.; 1-9. 7 acet.; 5. 2 al.; 0. 52 bz.; s. alk.; Cellosolve.			
4	Chloranil	Tetrachloroquinone	245. 9	294-295	Yellow leaflets or prisms.		(?)	<0.008 w.; 33 acet.; 16 eth.	Oral LD_{50} 4g/kg.	50% not toxic.	Irritant.[5]
5	p-Chloro-m-xylenol	p-Chloro-m-xylenol	156	112-115.5	White to creamy white crys.	Volatile in steam.	(?)	0. 0025 w.; 8. 1 bz.; 86. 6 al.; 50 isopropyl alc.; s. eth.		Absorbed.	
6	Compound G-4	2, 2'-Methylenebis-(4-chlorophenol)	269	179 (pure)	Almost white (pure); light pink to tan (technical).	10^{-10}(200°C); 10^{-4}(100°C)	High	1. 7 mg/100 ml w.; 76. 5 acet.; 1. 4 bz.; 42. 3 butanol.	Oral LD_{50}(?) 1g/kg.	None.	Low.
7	Copper naphthenate	Copper naphthenate	250-400		Semiviscous green fluid or green plastic mass.	0. 001 (100°C)	Usually 80%	0. 0015 w.; 8. isopropyl alc.; methyl ethyl ketone.			
8	Copper-3-phenyl-salicylate	Copper-3-phenyl-salicylate	490	148-152 d.	Tan, crystalline.	Non-volatile		0. w. to 5% by wt. in acet., bz., linseed oil, xylene.	Oral LD_{50} 0. 52g/kg.	None.	Low.
9	Crag 974	3, 5-Dimethyltetra-hydro-1, 3, 5, 2H-thiadiazine-2-thione	162. 2	100-103 d.	White crystalline powder.	1 psi absolute(30°C)	95%	0. 12 w. (30°C); 9. 4 acet. (30°C); 26 trichlorethane.	Oral LD_{50} 0. 5g/kg.	Slight when moist.	Slight.
10	Cresatin	Metacresyl acetate	150. 2	212 (boiling point)	Colorless, oily liquid.	Volatile with steam	Close to 100%	s. c. w.; s. h. w.; miscible in al., eth., chl., bz., pet. eth.			
11	Dichlone; Phygon	2, 3-Dichloro-1, 4-naphthaquinone	227	193	Yellow crystalline solid.	Slightly volatile		sl. s. w., most org. solvents, acet., dioxane.	Oral LD_{50} 1. 5g/kg.	Poor.	Irritant.
12	Dowicide 1	o-Phenylphenol	170. 2	57. 2	White or light buff to pink flakes.	Approx. 1 (100°C)	98% or higher	<0. 006 w.; >127 acet.; >110 ac. a.; 975 me. alc.; 257 pine oil.	Oral LD_{50} 2. 4-3. 1 g/kg	None.	Low.
13	Dowicide 6	Tetrachlorophenol (2, 3, 4, 6)	231. 9	56. 0	Light brown flakes to a sublimed mass.	Approx. 1 (100°C)	92%	<0. 1 w.; 370 acet.; 189 bz.; 392 al.; 412 eth.; 319 me. alc.	Moderately toxic orally.	Absorbed.	Slight.
14	Dowicide 7; Santophen	Pentachlorophenol	266. 3	190. 2(pure); 187-176 (technical)	White, needle-like crys. (pure); dark flakes and sublimed crys. (technical.)	$1.1 x 10^{-4}$ (20°C); 0.12 (100°C)	Usually 83%	14 ppm w. (20°C); 21. 5% acet. (20°C); 11. 0 bz. (20°C); 57. 0 me. alc. (20°C).	Oral LD_{50} 80mg/kg.	Absorbed.	Low; irritant; dust & vapor.[4, 5]
15	Glyodin	2-Heptadecylglyoxalidine acetate	368. 6	62-68	Light orange crystalline solid.	(?)		s. w., acet., toluene; s. (39%) isopropyl alc.	Oral LD_{50} 1. 34g/kg.	Slight.	Irritant.[3]
16	Milmer I; Bloquin; Copper-8	Copper-8-quinolin-olate	351. 8	Does not melt	Yellow-green powder.	Practically nil	85% or higher	<0. 002 w.; 0. 98 ac. a.; <0. 009 bz.; <0. 01 al.; s. chl.	Large.	None.	Slight.
17	p-Nitrophenol	p-Nitrophenol	139. 1	111. 4-114	Colorless or yellow prisms.	0. 083(100°C)	(?)	1. 6 w. ; 21. 2 h. w.; 54. 4 h. tol.; 189 sal.	s.c., MLD 0.6 g/kg(rabbit).		Slight.[6]
18	Phenylmercuric acetate	Phenylmercuric acetate	336. 7	149-153	Small white lustrous prisms.	Very low	(?)	0. 5 w.; 2. 9 h. w.; 8 al.; 1. 8 bz.; sl. s. pet. solvents.	S.c. LD_{50} 27mg/kg.	None, if/L causes blistering.	
19	Phenylmercuric oleate	Phenylmercuric oleate	558. 9	212 d.	Amorphous solid.	Non-volatile	10%	1. w.; s. most hydrocarbon solvents.	MLD about 133mg/kg.	Absorbed.	Irritant. 5
20	Pyridylmercuric stearate	Pyridylmercuric stearate	562. 2	120-130 d. at 200°C	White powder.			0. 01 w.; 0. 3 acet.; 0. 8% bz; 1. 5% gly.			
21	Semesan; Uspulun	2-Chloro-4-(hydroxy-mercuri)phenol	345. 2		Pink-white powder.	Low volatility		1. w., most org. solvents; s. a., alk.	Highly toxic	Absorbed.	Irritant.[7]
22	Shirlan	Salicylanilide	213	134-140; d. at 142°C	White crys. (pure), cream powder (technical).	Volatile with steam.	High	0. 005 w.; 47 acet.; 11. 6 al.; 8. 0 eth.; 49 ac. a	MLD about 1g/kg.	Poor.	None(?).
23	Sorbic acid	2, 4-Hexadienoic acid	112. 1	134. 5	Colorless solid. Colorless needles from water.	0. 01(20°C)	Close to 100%	0. 6 gly.; 5. 8 propylene glycol; 9. 2 acet. (20°C).	Oral LD_{50} 10. 5g/kg.	Poor.	Irritant. 8
24	Sulphur, lime	Calcium polysulfides			Orange-red liquid.	Non-volatile		1. w.	Oral LD_{50} 0. 25-0. 5g/kg.	Absorbed.	Slight; irritant, eye.
25	Thiram; Thirurad; Tuads	Tetramethyithiuram disulfide	240. 4	155-156	White powder or grains.			<0. 005 w.; 3. 1 acet.; 5. 0 bz.; 15 chl.; 1. 6 toluene.	Oral LD_{50} 860mg/kg.	Absorbed.	Irritant.[5]
26	Zineb	Zinc ethylenebisdithio-carbamate	275		White solid.	Negligible at 25°C		1. w.; s. pyr.	Oral LD_{50} 5. 2g/kg.	Poor.	Slight.
27	Ziram; Milban; Zimate	Zinc dimethyldithio-carbamate	305. 8	246(pure)[9]	White solid.	Negligible at 25°C		<0. 008 w.; 0. 33 acet.; 0. 74 chl.; s. CS_2	Oral LD_{50} 1. 4[4] 0. 1g/kg.[1]	Poor.	Irritant.[5]

/1/ Abbreviations: a. =acid; ac. a. =acetic acid; acet. =acetone; al. =ethyl alcohol(95%); alc. =alcohol; alk. =alkali; bz. =benzene; c. =cold; chl. =chloroform; crys. =crystals; d. =decomposes; dil. =dilute; eth. =ether; gly. =glycerol; h. =hot; i. =insoluble; me. =methyl; ML D=minimum lethal dose; org. =organic; pet. =petroleum; ppm=parts per million; ppt. =precipitate; pyr. =pyridine; s. =soluble; s. c. = subcutaneous; sl. =slight; tol. =toluene; w. =water. /2/ To nose and throat. /3/ 158-171 (technical). /4/ To skin and respiratory tract. /5/ To skin. /6/ May cause dermatitis. /7/ Strongly irritant and sensitizing. /8/ Eye injury in rabbits. /9/ 240-244 (technical).

The question "If you were limited to the use of only 25 drugs in your practice, which would you choose?" was presented to several hundred clinicians, dentists, and veterinarians throughout the United States. The total response, entailing some 600 compounds, was statistically analyzed and the results are tabulated below -- 30 drugs in each professional category listed in order of preference. Biologicals were not included.

	Drug[1]	Use
	CLINICIANS	
1	Atropine	Anti-parasympatholytic, antispasmodic, mydriatic.
2	Morphine	Analgesic, narcotic.
3	Penicillin	Antibiotic.
4	Adrenal cortical hormones (ACH)	In adrenal insufficiency, rheumatoid arthritis, rheumatic fever, allergies, hay fever, bronchial asthma.
5	Acetylsalicylic acid (Aspirin)	Analgesic, antipyretic.
6	Digitalis	Myocardial stimulant in congestive heart failure.
7	Tetracycline	Antibiotic.
8	Epinephrine (Adrenalin)	Sympathomimetic, antispasmodic, vasoconstrictor.
9	Vitamin B complex	In Vitamin B deficiencies.
10	Streptomycin	Antibiotic.
11	Codeine	Analgesic, sedative, narcotic, antitussive.
12	Phenobarbital (Luminal)	Long-acting sedative, hypnotic, antispasmodic.
13	Procaine (Novocaine)	Local anesthetic.
14	Thyroid	In replacement therapy, obesity, myxedema, low BMR.
15	Insulin	In diabetes mellitus, hypoglycemic shock therapy.
	DENTISTS	
31	Procaine (Novocaine)	See Item 13.
32	Eugenol (eugenic acid, allyl guaiacol)	Local anesthetic and antiseptic.
33	Codeine	See Item 11.
34	Epinephrine (Adrenalin)	See Item 8.
35	Acetylsalicylic acid (Aspirin)	See Item 5.
36	Alcohol, ethyl	Aid in drying cavities; see also Item 23.
37	Iodine (tincture)	Local antiseptic.
38	Nitrous oxide (N_2O)	Inhalation anesthetic and analgesic.
39	Penicillin	See Item 3.
40	Zinc oxide	In dental cements.
41	Lidocaine (Xylocaine)	Infiltration anesthesia; nerve block.
42	Oxygen	See Item 29.
43	Phenol	Local antiseptic and anesthetic.
44	Hydrogen peroxide (H_2O_2)	Bleaching and disinfecting agent; used in dentrifices, mouthwashes.
45	Creosote, beechwood	Local antiseptic and anesthetic; in sterilization of root canals.
	VETERINARIANS	
61	Tetracycline	See Item 7.
62	Penicillin	See Item 3.
63	Phenothiazine	Anthelmintic for pinworms, roundworms.
64	Procaine (Novocaine)	See Item 13.
65	Dextrose (glucose)	Parenteral nutrient solution.
66	Iodine (tincture)	See Item 37.
67	Pentobarbital (Nembutal)	See Item 22.
68	Calcium gluconate	In milk fever (cattle), preg. disease (sheep); in convulsions, eclampsia, paraplegia (cats, dogs); in Mg, Hg, Pb, CCl_4 poisonings.
69	Chloral hydrate	Narcotic, anesthetic; in tetanus, colic (horses), convulsions, strychnine poisoning.
70	Ether, diethyl	See Item 17.
71	Nemural (a diocarbyl)	Tenuacide.
72	Alcohol, ethyl	See Item 23.
73	Magnesium sulfate	Cathartic.
74	Hexachlorocyclohexane (Lindane)	Insecticide.
75	Morphine (salts)	See Item 2.
76	Posterior pituitary	Oxytocic, pressor, antidiuretic.

	Drug[1]	Use
16	Iron	In nutritional iron deficiencies.
17	Ether, diethyl	Inhalation anesthetic.
18	Sulfadiazine	Bacteriostat and bactericide.
19	Adrenocorticotropic hormone (ACTH)	In adrenal cortical insufficiency; see Item 4.
20	Meperidine hydrochloride (Demerol HCl)	Analgesic, antispasmodic; similar to morphine.
21	Gantrisin (a sulfisoxazole)	Wide-spectrum antibacterial.
22	Pentobarbital (Nembutal)	Hypnotic, sedative, antispasmodic.
23	Alcohol, ethyl	CNS depressant, sedative, nutrient, antiseptic, solvent.
24	Aminophylline	Diuretic antispasmodic, cardiac and respiratory stimulant.
25	Diphenylhydantoin sodium (Dilantin Na)	Anticonvulsant in epilepsy, chorea, and similar conditions.
26	Ephedrine	Sympathomimetic, vasoconstrictor, nasal decongestant.
27	Ergot	Oxytocics.
28	Chloramphenicol (Chloromycetin)	Wide-spectrum antibiotic.
29	Oxygen	With inhalation anesthesia; treatment or prevention of hypoxia.
30	Quinidine	In auricular fibrillation and tachycardia.
46	Ammonia, aromatic spirit	Analeptic in syncope; antacid.
47	Pentobarbital (Nembutal)	See Item 22.
48	Sodium fluoride	Inhibition of tooth decay.
49	Calcium hydroxide	Neutral base for temporary fillings and pulp capping.
50	Benzalkonium chloride (Roccal)	Surface antiseptic.
51	Silver nitrate	Antiseptic, astringent, caustic.
52	Zinc chloride	Antiseptic, astringent, caustic.
53	Glycerol	Solvent, emollient, plasticizer.
54	Ethylaminobenzoate (Benzocaine)	Local anesthetic.
55	Sodium bicarbonate	In mouth wash.
56	Gentian violet	Local antiseptic.
57	Phenobarbital (Luminal)	See Item 12.
58	Tetracycline	See Item 7.
59	Nitromersol (Metaphen)	Local antiseptic.
60	Petrolatum, liquid	Lubricant, solvent, vehicle.
77	Iron	See Item 16.
78	Streptomycin	See Item 10.
79	Petrolatum, liquid	See Item 60.
80	Arecoline hydrobromide	Teniacide for dogs, cats; cathartic for horses.
81	Sodium fluoride	Insecticide, anthelmintic for roundworms of swine.
82	Benzalkonium chloride (Roccal)	See Item 50.
83	Sulfamerazine	Bacteriostat.
84	Sulfamethazine	Bacteriostat.
85	Sulfaquinoxaline	Prevention and control of cecal and intestinal coccidiosis of fowl.
86	Tetrachloroethylene	Anthelmintic for hookworms.
87	Adrenal cortical hormones (ACH)	See Item 4.
88	N-Butylchloride (Chlorobutane)	Anthelmintic.
89	Epinephrine (Adrenalin)	See Item 8.
90	Acetylsalicylic acid (Aspirin)	See Item 5.

/1/ Drugs listed may include, or be interpreted in terms of, salts, closely related derivatives, or preparations. The eight drugs or drug types unanimously selected in all categories are: codeine (or morphine), acetylsalicylic acid, procaine, alcohol, epinephrine, a barbiturate (either phenobarbital or pentobarbital), penicillin, and tetracycline.

The symptoms indicated below may result from numerous pathological conditions or from exposure to many factors other than those given in the table. They may also vary in severity and order of appearance, according to the nature and amount of the toxic agent. This table lists examples of some common household poisons and therapeutic drugs which exert a toxic effect.

Part I: CHARACTERISTIC SYMPTOMS

	Symptom	Poison
	Circulatory	
1	Blood cell changes	Anemia: alcohol(chronic), arsenic, barbiturates(chronic), benzene(chronic), lead, morphine(addiction), naphthalene, sulfonamides; brown blood(Meth Hb): acetanilid, antipyrine, nitrites, nitrobenzene, nitroglycerin, phenacetin, potassium chlorate, sulfanilamide, sulfites; leucocytosis: chloral hydrate, pilocarpine, atropine; leucopenia: aminopyrine, aniline derivatives, arsenicals, benzene, sulfonamides; polycythemia: aniline derivatives(chronic), arsenic(dysentery); stippling: lead.
2	Bradycardia	Barium, digitalis, muscarine, physostigmine, pilocarpine, quinine, strophanhin, tetraethyl lead, veratrum.
3	Collapse(circulatory)	May be produced by practically any poison.
4	Hemorrhage, petechiae, purpura	Arsenic, benzene, corrosives, dicumarol, heparin, sedormid, warfarin.
5	Hypertension	Amphetamine, barium, ephedrine, epinephrine.
6	Hypotension	Apresoline, barbiturates(acute), chloroform, hexa- and pentanethonium compounds, histamine, muscarine, nitrites and nitroglycerin, tribromethenol, veratrum.
7	Tachycardia	Amphetamine, atropine, cocaine, ephedrine, epinephrine.
8	Vasoconstriction, gangrene	Amphetamine, ephedrine, epinephrine, ergot, lead, nicotine.
9	Coma or drowsiness	Alcohol, aniline, anesthetics, arsenic, antihistaminics, atropine, barbiturates, bromides, carbon disulfide, carbon monoxide, carbon tetrachloride, chloral hydrate, cyanides, gasoline, kerosene, methyl bromide, methylchloride, organic phosphate insecticides[1], opiates, synthetic morphine-like analgesics[2], phenol, sulfanilamide, sulfides.
10	Constipation	Calcium salts, dihydromorphinone, lead, opiates, synthetic morphine-like analgesics.[2]
	Convulsive	
11	Clonic	Abrin and castor beans, atropine, caffeine, camphor, carbon disulfide, ergot, insulin(inj.), phenol, picrotoxin, strychnine(early), theophylline.
12	Tonic or tetanic	Camphor, carbon monoxide, cocaine, cyanides, insulin(inj.), metrazol, nicotine, organic chloride insecticides[3], organic phosphate insecticides[1], procaine, strychnine.
13	Tremor	Alcohol, amphetamine, arsenic, barium, ergot, ephedrine, insulin(inj.), lead, manganese(chronic), mercury(chronic), nicotine, physostigmine.
14	Diarrhea	Abrin and castor beans, antimony, arsenic, barium, corrosives, croton oil, digitalin group, emetine, ergot, mercury, muscarine, nicotine, organic phosphate insecticides[1], physostigmine, pilocarpine.
15	Hyperthermia(fever)	Arsenicals, atropine, barbiturates(early), camphor, cocaine, dinitrophenols, phosphorus, sulfonamides, salicylates.
16	Hypothermia	Alcohol, anesthetics, aniline derivatives, chloral hydrate, coal tar analgesics and antipyretics, opiates and synthetic morphine-like analgesics(except demerol)[2], nitrites, phenol.
17	Mania or delirium	Alcohol(chronic), amphetamine, atropine, barbiturates(chronic), bromides, camphor, cannabis, cocaine, ephedrine, insulin(inj.), lead, mercury, phenol, physostigmine, scopolamine.
18	Odor of breath	Acetone(diabetes, ingestion, starvation), alcohol, ammonia, camphor, chloroform, cyanides, methylsalicylate, nitrobenzene, paraldehyde, phenols, phosphorus, sulfides, other odoriferous poisons.
19	Paralysis	Abrin and castor beans, alcohol, arsenic, barium, carbon disulfide, lead, nicotine, triorthocresyl phosphate.
	Pupillary	
20	Dilation	Alcohol, amphetamine, atropine, barbiturates, cocaine(early), ephedrine, homatropine, scopolamine.
21	Constriction	Codeine, ergot, opiates and synthetic morphine-like analgesics[2], muscarine, neostigmine, nicotine, organic phosphate insecticides[1], physostigmine, pilocarpine.
22	Fixation	Acetanilid, alcohol, anesthetics, chloral hydrate, coal tar analgesics, paraldehyde, somnifacients.
23	Respiratory depression	Alcohol, ANTU, barbiturates, barium, carbon disulfide, carbon tetrachloride, cyanides, opiates and synthetic morphine-like analgesics[2], organic phosphate insecticides[1].
	Sensory	
24	Abdominal pain and colic	Arsenic, barium, carbon disulfide, cathartics(drastic), corrosives, fluorides, lead, mercury, methyl alcohol, muscarine, nicotine, organic phosphate insecticides[1], oxalates, physostigmine, pilocarpine.
25	Blindness and deafness	Atropine, barium, cocaine, digitalis, ergot, methyl alcohol, nicotine, quinine, salicylates.
26	Color vision	Digitalis, santonin.
27	Paresthesia	Alcohol, arsenic, carbon disulfide, ergot, lead, mercury.
28	Vertigo	Alcohols, anesthetics, antihistaminics, barbiturates, carbon monoxide, cyanides, ergot, fluorides, gasoline, histamine, kerosene, methadione, nicotine, nitrites, opiates and synthetic morphine-like analgesics[2], quinine, salicylates.
	Dermal	
29	Corrosion(incl.mucosa)	Acids, alkalies, cresol, phenol.
30	Cyanosis	Acetanilid, alcohol, anesthetics, aniline, barbiturates, cyanides, gasoline, kerosene, nitrates, nitrobenzene, phenacetin, sulfanilamide, sulfides.
31	Discoloration (incl. tongue, oral mucosa)	Black: sulfuric acid; brown: bromine, iodine; greenish-blue: Paris green, other copper salts; white: alkalies, corrosive acids, metallic salts, phenol; yellow: nitric and picric acids; gingival line: bismuth, copper, lead, mercury, silver.
32	Dryness of mouth	Antihistaminics, atropine, ephedrine, scopolamine.
33	Edema	Arsenic, cortisone and derivatives, cresol, mercury, oxalates, phenol, turpentine.
34	Epilation	Alkali sulfides, radium, thallium.
35	Exfoliation	Arsenic, gold, sulfonamides.
36	Flush	Alcohol, anesthetics, arsenic, atropine, borates, carbon disulfide, carbon monoxide, cyanides, histamine, nicotinic acid, opium derivatives, pilocarpine.
37	Jaundice	Arsenic, bismuth, carbon tetrachloride, chloroform, cinchphen, gold, phosphorus, sulfonamides.
38	Pallor	Arsenic, barbital, cocaine and other local anesthetics, ephedrine, lead.
39	Rash	Can be caused by almost any drug, the more common being: antihistaminics, arsenicals, atropine, barbiturates, bromides, dyes, iodides, mercurials, procaine, quinine, radioactive substances, salicylates, sulfonamides.
40	Sweating	Acetanilid, antipyrine, emetics, opiates, phenacetin, physostigmine, pilocarpine, sulfonal.
41	Urticaria	Bromides, organic chloride insecticides[3], histamine, phenobarbital, salicylates, sulfonamides.
	Urinary	
42	Albuminuria	Arsenic, carbon tetrachloride, chlorates, chloroform, mercury, phenols, sulfonamides.
43	Color changes	Brown to black: naphthalene, phenol, pyrogallol, quinine, resorcinol; green: anthraquinone, methylene blue; orange: santonin; red: anthraquinone dyes, phenolphthalein(alkaline), santonin(alkaline).
44	Glycosuria	Ephedrine, morphine and opiates.
45	Hematuria	Arsenic, cantharides, mercury, naphthalene, oxalates, phenols, sulfonamides.
46	Oliguria	Arsenic, carbon tetrachloride, chromate, mercury(late stages), oxalates, phenols, sulfonamides.
47	Odor	Turpentine.
48	Polyuria(early); anuria(later)	Mercurials.
	Vomiting	
49	Gastrointestinal irritation	Abrin and castor beans, alcohol, alkaline sulfides, antibiotics, antimony, arsenic, copper, cyanides, emetine and other ipecac alkaloids, gasoline, iodine, kerosene, mercury, naphthalene, phenol, strong acids and alkalies(also ammonia).
50	Systemic poisoning	Antihistaminics, apomorphine, atropine, camphor, carbon disulfide, cyanides, DDT(??), digitalis and other cardiotonic glycosides, emetine and other ipecac alkaloids, nicotine, organic chloride insecticides[3], organic phosphate insecticides, phenol, picrotoxin, quinine, salicylates, strychnine, sulfonamides.

/1/ DFP, HETP, malathion, parathion, TEPP, etc. /2/ Levorpan(dromoran), meperidine(demerol), methadone, etc. /3/ Chlordane, lindane, etc.

355. COMMON POISONS: SYMPTOMS, PROCEDURES, AND ANTIDOTES (Concluded)

The symptoms indicated below may result from numerous pathological conditions or from exposure to many factors other than those given in the table. They may also vary in severity and order of appearance, according to the nature and amount of the toxic agent. This table lists examples of some common household poisons and therapeutic drugs which exert a toxic effect.

Part I: CHARACTERISTIC SYMPTOMS (concluded)

	Symptom	Poison
51	Vomiting (concluded) Vomitus, colored	Blue: with iodine if starch is present; brown or "coffee grounds": alkaline or acid corrosives; green: copper sulfate, Paris green, Scheele's green.

Part II: GENERAL PROCEDURES

Poisons Taken Orally

1 If nature of poison is unknown, give 15g of "universal antidote" (finely powdered activated charcoal, 2 parts; tannic acid, 1 part; magnesium oxide, 1 part) in half a glass of warm water; if this preparation is not available, give large amounts of water, tea, milk or eggs. If poison is known, give specific antidote. Caution: Never give anything by mouth to an unconscious person.

2 Induce vomiting by stroking back of tongue from side to side, or by giving plenty of warm salt water or soapy water; or wash stomach promptly by means of tube. Caution: Do not use these procedures (a) where corrosive poisons have been ingested >30 minutes (danger of perforation of stomach or esophagus), or (b) in strychnine poisoning (danger of convulsions). With infants, avoid aspiration of vomitus into trachea or lungs by placing child face down when first retching appears, with head at least 8-10 inches lower than hips. Apomorphine injected subcutaneously is very effective emetic, but should be avoided in coma or respiratory depression.

3 Give cathartic, 15g of sodium sulfate or 30g of magnesium sulfate in half a glass of water; flush bowel by high colonic irrigation with warm water.

Poisons Inhaled

4 Try to identify toxic vapor. In areas contaminated with ammonia, arsine, carbon monoxide, chlorine, bromine, fluorine, hydrogen cyanide, hydrogen sulfide, nitric vapors, or other highly toxic gases (i.e., CW agents), proper masks should be worn or the breath held.

5 Remove the victim promptly from exposure.

6 At first sign of difficult breathing begin artificial respiration, using approved method; oxygen should be administered only by trained personnel; continue artificial respiration until professional medical personnel arrive.

Poisons in Contact with the Skin

7 Try to identify the poison, avoiding personal contact with it.

8 Flood the contaminated area with successive increments of water for at least 15 minutes.

9 Remove all contaminated clothing, including gloves, headgear, shoes, watches, rings, jewelry.

10 Do not use oils, fats or pastes (sodium bicarbonate, etc.), or bandages, unless specifically indicated.

Poisons in Contact with the Eyes

11 Promptly flood both eyes with copious amount of water, with the eyelids can be opened and held apart by grasping the eyelashes and pulling the eyelids away from the eyeball). Using this method, continue washing for at least 15 minutes.

Other Precautions

12 Keep the patient warm and in a recumbent position; never leave him unattended.

13 If breathing is difficult or has stopped, give artificial respiration, and continue until voluntary respiration reappears or medical aid arrives.

14 Do not give alcoholic beverages except on proper medical advice; alcohol increases the absorption of some poisons.

15 Send for medical assistance as soon as possible, but do not interrupt the procedures outlined above.

Part III: SPECIFIC ANTIDOTES

The "General Procedures" (G. P.) referred to below are found in Part II above.
i. m. = intramuscular injection; i. v. = intravenous injection; s. c. = subcutaneous injection.

	Poison	Antidote
1	Acids, strong (CH_3COOH, HCl, HNO_3, H_2SO_4, H_3PO_4)	Use G. P. 1, or milk of magnesia; do not give carbonates or emetics.
2	Alcohol, methyl (wood alcohol)	Use G. P. 2, 3; 3-5% sodium bicarb. and 5% glucose, i. v., or orally if patient in conscious.
3	Alkalies, strong ($NaOH$, KOH, NH_4OH, K_2CO_3, Na_2CO_3)	Large amounts 1% acetic acid or vinegar (4 x dil.) orally, then milk, white of eggs; do not use stomach tube or induce vomiting
4	Alkaloids	Use G. P. 1, 2, 3, or gastric lavage with 0.01% potassium permanganate.
5	Belladonna (atropine, hyoscyamine, solanine, stra-	Same as above, then pilocarpine i. v., and pentobarbital i. m. or i. v.
6	Cocaine monium)	Use G. P. 1, 2, 3; pentobarbital i. m. or i. v., to control convulsions.
7	Ergot (ergotoxine, etc.)	Use G. P. 1, 2, 3; amyl nitrite inhalation, nitroglycerin s. c., papaverin i. v.
8	Muscarine, physostigmine, pilocarpine	Atropine i. v. or s. c. immediately and until symptoms are controlled, then G. P. 1, 2.
9	Nicotine (tobacco, "Black Leaf 40")	Ephedrine i. m., or amphetamine i. v. Do not give strychnine. G. P. 1, 2.
10	Opium (codeine, heroin, laudanum, morphine), synthetic morphine-like analgesics.	Gastric lavage with 0.1% potassium permanganate; N-allyl morphine i. v. ; caffeine, sodium benzoate s. c., to stimulate respiration.
11	Strychnine	Pentobarbital i. v. immediately, or inhalation anesthesia to control convulsions; gastric lavage with 0.1% potassium permanganate only after convulsions have ceased; keep quiet, in absolute darkness; no morphine.
12	Arsenicals (As_2O_3, Fowler's sol., Paris green, insecticides, rodenticides, Scheele's green)	G. P. 1, 2, 3; then BAL^1 i. m., repeated doses; 30-60g Na or Mg sulfate in warm water, orally.
13	Barbiturates (barbital, luminal, nembutal, pentobarbital, phenobarbital, veronal)	G.P. 1, 2amphetamine, metrazol or picrotoxin i.v., repeated until muscle excitation or recovery.
14	Barium salts (acetate, chloride, carbonate, sulfide)	Sodium or magnesium sulfate in warm water, orally; G. P. 2, 3.
15	Chloral hydrate	Gastric lavage with tea or coffee; picrotoxin, amphetamine or ephedrine i. v. until conscious.
16	Cyanides (HCN, KCN, NaCN)	Amyl nitrite inhalation immediately, then 3% sodium nitrite i. v. and 25% sodium thiosulfate i. v.
17	Formaldehyde (ingested)	Milk, eggs, ammon. acetate (15g in glass of water), or 0.2% ammonia water freely by mouth; G. P. 2.
18	Fluorides [HF, NaF, NH_4F, Na fluoroacetate (1040)]	Ca gluconate i. v. immed.; glass of lime water or 1% of $CaCl_2$ orally, or as gastric lavage.
19	Halogens (bromate, bromine, chlorate, iodine)	Sodium thiosulfate 15g in glass of water or starch solution; G. P. 2 and 3.
20	Lead compounds	Acute: gastric lavage with magnesium, sodium or aluminum sulfate solution, followed with plain water to remove lead sulfate thus formed; milk, eggs. Chronic: sodium calcium versenate 3% in glucose solution, by slow intravenous drip.
21	Mercury compounds	Orally, glass of 5-10% sodium phosphite or sodium formaldehyde sulfoxalate solution; G. P. 2, 3; BAL^1 i. m.
22	Organic and fluorophosphates [diisopropyl fluorophosphate (DFP), hexaethyltetraphosphate (HETP), "nerve gas," parathion, tetraethylpyrophosphate, etc.]	Atropine sulfate i. m. or i. v. immediately, until symptoms subside; if poison swallowed, give milk, induce vomiting (G. P. 2); long-continued artificial respiration may be necessary.
23	Oxalic acid and oxalates	Orally or by stomach tube, lime water, magnesium oxide, chalk, or soluble calcium or magnesium salts; gastric lavage if mucosa not deeply corroded (burning pain, collapse); 10% calcium gluconate or 5% calcium chloride i. v. for tetany; later, magnesium sulfate purge.
24	Phenols (carbolic acid, creosote, cresol, etc.)	Give olive oil by mouth; carefully pass small, well-lubricated tube and wash out stomach with olive oil; if olive oil not available, give milk or egg white. Skin: wash with 50% alcohol, glycerine, vegetable oils, or soapy water.
25	Phosphorus, yellow (rat poisons)	Copious, repeated gastric lavage with 1-2% copper sulfate or 0.1-1% potassium permanganate solutions, or normal saline; G. P. 3; no oils, fats or milk in diet.
26	Salicylates [acetylsalicylic acid (aspirin), methyl salicylate (oil of wintergreen), phenyl salicylate (salol), salicylic acid, sodium salicylate]	Gastric lavage with sodium bicarbonate, saline cathartic, glucose i. v. ; stimulants.
27	Silver salts ($AgNO_3$)	Sodium chloride or tannic acid in water; G. P. 2, followed with milk or other demulcents.
28	Thallium salts (insecticides, rodenticides)	Gastric lavage with 1% sodium or potassium iodide; G.P. 2; stimulants, demulcents; BAL^1 i. m.

1/ BAL (British anti-lewisite); 2, 3-dimercapto-1-propanol; used as a 10% solution in peanut oil with 20% benzyl benzoate.

A = Bradykininogen; B = Carboxypolypeptidase; C = Catalase; D = Cephalinase; E = Cholinesterase; F = Deoxyribonuclease; G = Diaminoxidase; H = Ithinase; P = Lipase; Q = 5-Nucleotidase; R = Phospholipase; T = Phosphodiesterase; U = Phosphomonesterase; V = Polypepti-

	Animal, Distribution	Adult Length ft	Fibrinogen		Prothrombin		Enzyme Activity[1]	Mouse Toxicity[2] mg/kg
			Coagulate	Destroy	Activate	Destroy		
	Helodermatidae							
1	Gila monster (Heloderma suspectum), S.W.U.S.A., N.W. Mexico (chiefly Arizona and Sonora)	1½-2						LD_{50} (rat)20.18 lyophilized venom
	Colubridae[7] (Snakes)							
2	Boomslang[8] (Dispholidus typus), forested portions of Africa south of Sahara	4½-5½			+(?)		W	MLD 10.0
	Elapidae[9] (Snakes)							
3	Adder, death (Acanthophis antarcticus), most of Australia, parts of New Guinea, nearby islands	2-3	+(?)		+(?)		E, L, N, O, R	LD_{100} (0.5-0.7)
4	Black, red-bellied (Pseudechis porphyriacus), E. Australia	4½-5½	+(?)		+(?)		N, O	LD_{100} 3.5
5	Brown, Australian (Demansia textilis), most of Australia	4-5					E, N, R	LD_{100} 0.25
6	Brown, giant or Taipan[11] (Oxyuranus scutellatus), N. Australia	8-11	+(?)		+(?)			LD_{100} 0.17
7	Cobra, Indian (Naja naja), S. Asia to Indonesia, Formosa, Philippines	4-6	-	-	-	+	B, E, H, I, J, L, M, N, O, P, R, T, U, V, W	MLD 0.75 LD_{50} 0.5
8	Cobra, king[11] (Ophiophagus hannah), W. India, Burma, Philippines, Indonesia, S. China, Thailand	12-16					E, N, R	
9	Cobra, spitting (Naja nigricollis), Africa south of Sahara in savannah areas	5-6				+	E, L, N, R, W	MLD 0.5
10	Copperhead, Australian[14] (Denisonia superba), E. Australia	4½-5½	+(?)		+(?)		E, L, N, O, R	LD_{100} 1.2
11	Coral, Central American (Micrurus nigrocinctus), tropical Mexico through Panama	2-3½						
12	Coral, North American (M. fulvius), southern U.S.A. to N.E. Mexico	2-3½						LD(MLD?) 1.0
13	Coral, South American (M. frontalis), southern Brazil to northern Argentina	2-5	-	-	+	-	L, W	LD_{100} 2.5
14	Coral, subtropical (M. corallinus), subtropical South America	2-4					E, L, N, R	
15	Krait, common (Bungarus candidus coeruleus), India, Burma, Malay Peninsula, Java, Sumatra, Celebes	3½-4½					E, K, L, N, W	LD_{100} 3.0 LD_{50} 1.0
16	Krait, Formosan (B. multicinctus), S.E. China, Formosa	3-4		-(?)		-(?)		LD 0.1
17	Long-glanded[17] (Maticora intestinalis), Burma, Malay Peninsula, Java, Sumatra	1½-2						
18	Mamba, eastern green (Dendroaspis angusticeps), E. Africa, Ethiopia to Natal	6-13						MLD 0.75
19	Mamba, western green[15] (D. viridis), W. Africa	6½-8					E, L	LD_{100} 3.0
20	Ringhals (Hemachatus haemachatus), S. Africa	3-4	+	-	±	±	E, N, R, T, U, W	LD_{50} 3.0
21	Tiger[11] (Notechis scutatus), most of Australia including Tasmania	4-5½	-	-	+	-	E, L, N, R, T, U, W	LD_{100} 30-24 LD_{50} (g. pig) 6.5 µg/kg
	Viperidae[16] (Snakes)							
22	Adder, night (Causus rhombeatus), most of Africa	2-3					W	MLD 15.0
23	Adder, puff (Bitis arietans), Africa, S. Arabia	2½-5	-	+	-	-	A, E, N, R, T, U, W	MLD 7.5
24	Viper, European (Vipera berus), British Isles, across N. Europe and Asia to Japan	1½-2½					A, N	Mean LD 6.5
25	Viper, gaboon[22] (V. gabonica), tropical Africa	4-5½	+	+			E, L, N, Q, R, S, W	MLD 20.0
26	Viper, horned or Sahara sand (Cerastes vipera), N. Africa, Arabia, S. Iraq[23]	1½-2					N	MLD 15.0
27	Viper, Jura (Vipera aspis), Central and S. Europe	2-3		+		+(?)	E, G, L, N, O, R, W	MLD 0.75
28	Viper, mountain (V. lebetina), S.E. Europe to Pakistan[24]	3½-5					E, N	Mean LD 22.0
29	Viper, Palestine (V. palestinae), Israel and surrounding area							
30	Viper, Russell's, Daboia, or Tic polonga (V. russellii), India, Burma, S. China, Formosa, Java[25]	4-5½	+	-	-	+	B, E, H, I, J, K, L, M, N, O, P, Q, R, T, U, V, W	MLD 1.0 LD_{50} 20.0
31	Viper, saw-scaled[26] (Echis carinata), India, Iraq, Arabia, Africa north of equator[27]	1½-2½	+				B, E, I, J, L, N, R, V, W	MLD 5.0 LD_{50} 7.5
32	Viper, Sudan mole[28] (Atractaspis microlepidota), eastern central Africa	1½-2½						
	Crotalidae[29] (Snakes)							
33	Bolcotiara (Bothrops cotiara), southern Brazil, northern Argentina	1½-3					E, L, N	LD_{100} 15.0
34	Bushmaster[30] (Lachesis muta), Costa Rica to northern South America	8-11					L, W	LD_{100} 57.0

/1/ Implies characteristic activity for enzyme but not its specific isolation. /2/ Dry venom administered subcutaneously unless otherwise stated. rificus, C. atrox, C. horridus. /3/ GOOD implies a mortality of less than 1%; FAIR, 2-10% mortality; GUARDED, 11-40% mortality; POOR, mor- for crotalid envenomation believed effective. /7/ Fangs rear, immovable, grooved; over 1000 species (few poisonous, none dangerously). /8/ Ar- /11/ Large, aggressive; long fangs. /12/ Also Cape cobra (N. nivea), S.W. Africa and Cape Province; Egyptian cobra (N. haje), N.E. and S. Africa; /15/ Also banded krait (B. fasciatus). Slightly lower mortality. /16/ Mortality 77%. /17/ Venom glands extend through anterior third of body. /18/ Ar- ammodytes), S.E. Europe and Asia Minor; fair prognosis, symptoms somewhat more severe. /22/ Heavy snake, very long fangs. /23/ In arid gressive; chiefly arid habitat. /28/ Small, burrowing snake; large fangs. /29/ Fangs front, movable, hollow, pit between eye and nostril; more than

CHEMICAL AND BIOLOGICAL CHARACTERISTICS

Diastase; I = Dipeptidase; J = Endopeptidase; K = Flavin adenine dinucleotide; L = Hyaluronidase; M = Invertase; N = L-Amino-acid oxidase; O = Leccase; W = Protease. Slash mark (/) through letter indicates enzyme activity not known to be present.

Symptoms of Envenomation in Man	Prognosis[3]	Available Antiserum	
Helodermatidae			
Local pain, swelling, hyperemia, weakness, hyperpnea, tinnitis, nausea, vomiting. Death by respiratory paralysis and cardiac failure.[4]	(?)[5]	No[6]	1
Colubridae[7] (Snakes)			
Local pain, swelling and hemorrhage, ecchymoses, bleeding from nose and mouth, sometimes from all mucous membranes and skin, headache, vomiting, collapse; temperature normal or subnormal.	Good	No	2
Elapidae[8] (Snakes)			
Similar to poisoning by tiger except that peripheral circulatory failure is more common and hemorrhagic phenomena occur.	Guarded	Yes	3
Local pain and swelling, vomiting, hemorrhages from nose and mouth, prostration, hematuria.[10]	Good	Yes	4
Latent period to 12 hr followed by abdominal pain, vomiting, headache, dizziness, weakness, rapid pulse and subnormal temperature, respiratory and circulatory collapse, hemoglobinuria and peripheral thromboses.	Guarded	Yes	5
Similar to tiger. Flaccid paralysis of limbs, intercostal and bulbar paralysis, often rapidly fatal.	Poor	Yes	6
Pain radiating from bite, edema, numbness, tremors, ptosis, drooping of head, salivation, speech difficulty, giddiness, muscular incoordination and weakness, blindness, progressive depression of respiration, convulsions, incontinence of urine and feces. Pupils react to light and heart beats after respiration ceases.[12]	Guarded	Yes	7
Similar to poisoning by Naja spp. Symptoms develop rapidly, often death in 30-60 min.	Poor	Yes	8
Similar to poisoning by Naja spp. Frequently sprays venom at eyes. Contact produces acute, intense ophthalmia. Systemic poisoning does not occur by this route, and permanent damage to vision is rare.	Guarded	Yes	9
Similar to tiger. Rapid loss of muscle tone and consciousness, peripheral circulatory failure.	Guarded	Yes	10
Local numbness; minimal systemic symptoms. Few cases reported.	Fair (?)	No	11
Cyclic pains radiating from bite; somnolence, dyspnea, dysphagia, sweating; soreness of face, throat and eyes.	Guarded	No	12
Neurologic symptoms at site of bite; involvement of 3rd, 4th and 6th cranial nerves producing ptosis and diplopia. Prolonged coagulation time.	Guarded	Yes	13
Numbness without pain at bite. Early: headache, swelling of face and lips; hyperesthesia, sore throat, ptosis, photophobia, normal pupillary reflex, vomiting, cramps, dyspnea, loss of muscle tone, tachycardia. Later: backache, irritability, salivation, bradycardia, dysuria, albuminuria.	Guarded	Yes	14
Little immediate pain or local reaction. Latent period to 12 hr followed by abdominal pain, staggering gait, dysphagia, dyspnea, ptosis, stiffness of jaws, coma, respiratory paralysis, cardiac failure.[15]	Poor[16]	Yes	15
Poisoning similar to common krait.	Guarded	Yes	16
Minimal local pain and edema. Later: faintness, unsteady gait, periods of mental confusion, choking sensation with swelling and soreness of throat and mouth, salivation, vomiting, diarrhea, sweating, dyspnea.	Good (?)	No	17
Local pain and swelling, vomiting, restlessness, drowsiness or collapse followed by coma. Dyspnea and respiratory failure.	Poor	Yes	18
Poisoning similar to D. angusticeps.	Guarded	Yes	19
Pain, dyspnea, weak, thready pulse; cyanosis; collapse. Sprays venom at eyes. Effects resemble N. nigricollis.	Fair	Yes	20
Latent period 15-60 min followed by nausea, vomiting, faintness, drowsiness, sweating. Later: dullness of sensation, staggering, dysphagia, slurred speech, ptosis, pupils dilated and do not react to light; rapid, weak pulse and respiration, progressive dyspnea and death from respiratory failure.	Poor	Yes	21
Viperidae[20] (Snakes)			
Local hemorrhages, swelling.	Good	Yes	22
Severe local edema, necrosis and sloughing, restlessness, weak pulse, dyspnea, gastrointestinal hemorrhages.	Guarded	Yes	23
Local pain and edema of bitten extremity, sometimes extending into trunk; hemorrhages along lymphatics. Little systemic reaction, sometimes vomiting, sweating, abdominal pain, faintness, cyanosis, shock.[24]	Good	Yes	24
Pain, hemorrhagic edema, necrosis, severe shock, respiratory depression, pain in loins with hematuria, pupils dilated and do not react to light.	Guarded	Yes	25
Local pain, edema, fever, thromboses and cardiac collapse in severe cases.	Fair	Yes	26
Similar to V. berus but systemic symptoms prominent. Vomiting, diarrhea, dysuria, weakness, depression.	Good	Yes	27
Rapidly spreading edema and necrosis, cold sweat, thirst, nausea, vomiting. Severe cases show epistaxis and hematuria.	Fair	Yes	28
Local pain, edema, ecchymoses, abdominal pain, vomiting, diarrhea with bloody stools in severe cases, fever, peripheral vascular collapse and shock. Autopsy: serosanguineous transudate in subcutaneous tissue and muscles with degeneration of arteriole and capillary walls. Visceral hemorrhages especially under endocardium and in gastrointestinal mucosa.	Fair	Yes	29
Rapidly spreading edema with extravasation of blood, epistaxis and petechiae, abdominal pain, vomiting, paralytic ileus, collapse, shock, albuminuria, prolonged clotting time. Terminally: loss of consciousness, pupils fail to react to light, circulatory failure. Autopsy: subcutaneous hemorrhages especially near bite, meningeal congestion, blood in lungs.	Guarded	Yes	30
Local pain and edema, low platelet count with ecchymoses and hemorrhages from mucous membranes, profound anemia, abdominal pain, impaired liver function.	Guarded	Yes	31
Local pain followed by numbness, adenitis, tachycardia, sweating, salivation, vomiting, dyspnea and pulmonary congestion, microscopic hematuria.	Fair	No	32
Crotalidae[29] (Snakes)			
Inadequate information. Presumably similar to fer-de-lance.	Fair	Yes	33
Inadequate information. Rapid death preceded by a severe shock-like state.	Poor[31]	Yes	34

Considerable geographic and individual variation in toxicity exists, e.g., Ancistrodon contortrix, Bothrops jararacussu, B. neuwiedii, Crotalus terrality in excess of 40%. /4/ Nonaggressive, bite sometimes ineffective. /5/ Prognosis from good to poor, literature conflicting. /6/ Antiserum boreal, timid. /9/ Pages front, grooved though virtually fused for most of length; over 150 species. /10/ Also Mulga snake (P. australis). black cobra (N. melanoleuca), W., Central and E. Africa south of Zululand in forests. /13/ Highly aggressive. /14/ Sluggish, seldom bites. boreal, quick, aggressive. /19/ Active, aggressive; short fangs. /20/ Fangs front, movable, hollow; about 50 species. /21/ Also sand viper (V. habitat. /24/ Occurs in mountains to 8000 ft. /25/ Often common in thickly settled areas. /26/ Also called carpet viper or phoorse. /27/ Ag-80 species. /30/ Very aggressive, jungle habitat. /31/ Mortality usually 100%.

A = Bradykininogen; B = Carboxypolypeptidase; C = Catalase; D = Cephalinase; E = Cholinesterase; F = Deoxyribonuclease; G = Diaminoxidase; H = ithinase; P = Lipase; Q = 5-Nucleotidase; R = Ophio-ATP-ase; S = Phospholipase; T = Phosphodiesterase; U = Phosphomonoesterase; V = Polypeti-

	Animal, Distribution	Adult Length ft	Fibrinogen: Coagulate	Fibrinogen: Destroy	Prothrombin: Activate	Prothrombin: Destroy	Enzyme Activity[1]	Mouse Toxicity[2] mg/kg
		Crotalidae[49] (concluded)						
35	Cascabel (Crotalus terrificus), southern Mexico to Uruguay and Argentina, mostly in highlands	4-5½	+	-	A	-	E, F, L, N, R, W	LD_{100} 1.1 LD_{50} 0.6
36	Copperhead, North American (Ancistrodon contortrix), eastern and southern U.S.A.	2-3½					E, N, T, U, W	LD_{100} 53.0 LD_{50} 25.6
37	Fer-de-lance[32] (Bothrops atrox), central Mexico to eastern Argentina, islands of Martinique, Tobago, Trinidad, and St. Lucia	4½-6½	+	-	-	+	E, F, L, N, R, W	LD_{100} 31.0 LD_{50} 22.0
38	Habu (Trimeresurus flavoviridis), Riu Kiu Islands	4-5					R, T, U, W	LD_{100} 16.0
39	Jararaca (Bothrops jararaca), Brazil to northern Argentina and Paraguay	3½-4½	+	-	+	-	A, E, J, L, N, R, W	LD_{100} 7.0
40	Jararaca, painted (B. neuwiedii), Brazil and Bolivia to Argentina	2-3					E, F, L, N, R, W	LD_{100} 14.0[34]
41	Jararacussu (B. jararacussu), Bolivia, Brazil, Paraguay, Argentina	4-6					E, F, L, N, W	LD_{100} 9.0
42	Massasauga or marsh rattlesnake (Sistrurus catenatus), southern Ontario, central and S.W.U.S.A.	2-3					E, N, R	LD_{100} 9.0 LD_{50} 5.2
43	Moccasin, water (Ancistrodon piscivorus), southern U.S.A. to central Texas	3-5	-	+	-	+	D, E, K, L, N, O, Q, T, U, W	LD_{100} 45.0 LD_{50} 25.8
44	Rattlesnake, eastern diamondback (Crotalus adamanteus), S.E.U.S.A. in lowlands	4½-6½	+	+	-	-	D, E, L, N, Q, T, U, W	LD_{50} 14.5
45	Rattlesnake, Mexican diamondback (C. basiliscus), western Mexico	4½-6½	+	-	-	-	E, N, R, W	LD_{100} 4.0
46	Rattlesnake, prairie or Pacific (C. viridis), western U.S.A., S.W. Canada, N. Mexico	2½-5					E, N	LD_{50} 3.6
47	Rattlesnake, red[35] (C. ruber), extreme S.W.U.S.A., parts of California (Baja)	3-5					E, N	LD_{50} 21.2
48	Rattlesnake, timber (C. horridus), eastern U.S.A.	3-5	+	-	-	+	E, N, R, W	LD_{100} 9.2[36]
49	Rattlesnake, western diamondback[32] (C. atrox), S.W.U.S.A., northern Mexico	3½-5½	-	+	-	-	A, E, L, N, R, W	LD_{100} 19.0 LD_{50} 7.5[37]
50	Sidewinder or horned rattlesnake (C. cerastes), S.W.U.S.A. in deserts	1½-2½						LD_{50} 4.2
51	Timbo or jumping viper (Bothrops mexicana), southern Mexico through Central America	2-3	+	-	-	-	E, N, W	
52	Urutu (B. alternata), southern Brazil to Argentina	3-5					E, F, L, N, O, W	LD_{100} 23.0 LD_{50} 13.0
53	Viper, Chinese pit (Trimeresurus mucrosquamatus), S. E. China, Formosa	3-4						MLD 7.6
54	Viper, hognosed (Bothrops lansbergii), Central America, Panama to El Salvador	1-1½						
55	Viper, Malay pit (Agkistrodon rhodostoma), Thailand, Java, Malay Peninsula, Sumatra	2-3						
56	Viper, palm[49] (Bothrops schlegelii), British Honduras to Ecuador and Columbia	1-3	+				W	

/1/ Implies characteristic activity for enzyme but not its specific isolation. /2/ Dry venom administered subcutaneously unless otherwise stated. rifticus, C. atrox, C. horridus. /3/ GOOD implies a mortality of less than 1%; FAIR, 2-10% mortality; GUARDED, 11-40% mortality; POOR, mor- 30%. /34/ 26 mg/kg also reported. /35/ Nonaggressive. /36/ 36 mg/kg also reported. /37/ 16.8 mg/kg also reported. /38/ Also Matsushi or

	Toad, Distribution	Bufagins[1] Name (Proposed Formula)	Bufagins[1] Action or Effect[4]	Bufagins[1] Toxicity[5] mg/kg	Bufotoxins[2] Name (Proposed Formula)
1	Bufo alvarius, S.W. U.S.A.	Absent			Alvarobufotoxin
2	Bufo arenarum, Argentina	Arenobufagin ($C_{25}H_{34}O_6$)	Digitalis-like; emesis; systolic standstill of heart.	0.092 ±0.005	Arenobufotoxin ($C_{39}H_{60}O_{11}N_4$)
3	Bufo bufo bufo (B. vulgaris), Europe	Absent			Vulgarobufotoxin ($C_{38}H_{60}O_{11}N_4$)
4	Bufo bufo gargarizans, China	Cinobufagin ($C_{26}H_{34}O_6$)[7] Telecinobufagin ($C_{24}H_{34}O_5$)	Digitalis-like action on vagus, vagus center, myocardium; emesis; clonic or tonic convulsions after paralysis.	0.219 ±0.011 0.102 ±0.007	Cinobufotoxin ($C_{43}H_{64}O_{12}N_4$, or $C_{39}H_{58}O_{11}N_4$)
5	Bufo formosus (Bufo bufo japonicus), Japan	Gamabufagin ($C_{27}H_{38}O_6$)	Digitalis-like action; emesis; ventricular fibrillation.	0.101 ±0.005	Gamabufotoxin ($C_{41}H_{64}O_{11}N_4$)
6	Bufo marinus (B. aqua), circumtropical	Marinobufagin[8] ($C_{24}H_{32}O_5$)		0.555 ±0.028	Marinobufotoxin ($C_{38}H_{58}O_{10}N_4$, or $C_{42}H_{62}O_{11}N_4$)[9]
7	Bufo quercicus, S.E. U.S.A.	Quercicobufagin ($C_{23}H_{34}O_6$)		0.097 ±0.004	Quercicobufotoxin
8	Bufo regularis pardalis, South Africa	Regularobufagin ($C_{23}H_{34}O_5$)		0.153 ±0.006	Regularobufotoxin ($C_{37}H_{60}O_{10}N_4$)
9	Bufo terrestrius-americanus, E. U.S.A.	Americobufagin	Digitalis-like action.		Americobufotoxin
10	Bufo vallicepa, eastern Mexico, Texas and Louisiana	Vallicepobufagin ($C_{23}H_{34}O_5$)	Nausea; emesis; A-V block and ventricular standstill.	0.201 ±0.017	Vallicepobufotoxin
11	Bufo viridis viridis, Europe	Viridobufagin ($C_{23}H_{34}O_5$)	Nausea, emesis, increased intestinal tone, ventricular fibrillation.	0.111 ±0.008	Viridobufotoxin ($C_{37}H_{60}O_{10}N_4$)
12	Bufo woodhousei, S.E. U.S.A.	Fowlerobufagin ($C_{23}H_{33}O_6$)	Digitalis-like action; emesis; ventricular fibrillation.	0.218 ±0.012	Fowlerobufotoxin

/1/ The bufagins are steroid-type compounds and possess a digitalis-like action. /2/ The bufotoxins are the conjugation product of the specific buflethal or average fatal dose for cat, intravenous. /6/ Frog heart; heart perfusion method. /7/ Also reported $C_{29}H_{38}O_7$. /8/ Also reported as oc-

Diastase; I = Dipeptidase; J = Endopeptidase; K = Flavin adenine dinucleotide; L = Hyaluronidase; M = Invertase; N = L-Amino-acid oxidase; O = Leciase; W = Protease. Slash mark (/) through letter indicates enzyme activity not known to be present.

Symptoms of Envenomation in Man	Prognosis[3]	Available Anti-serum	
Crotalidae[2,9] (concluded)			
Little local reaction other than swelling, intense headache, nausea, dizziness, blindness, paralysis of neck and of eyelids (ptosis), collapse, albuminuris and hematuris followed by anuris. Death from respiratory paralysis or uremia. Autopsy: hyperemia of brain and meninges, sometimes with hemorrhages; intermediate nephron necrosis.	Poor	Yes	35
Local pain, swelling and necrosis, lymphagitis and lymphadenitis, sweating, nausea, vomiting. In severe cases: shock, petechiae, bloody stools.	Good	Yes	36
Local pain, edema and lymphadenopathy, bleeding from fang punctures, gums, nose and other body orifices, low prothrombin, prolonged clotting time, moderate to high leukocytosis, hematuris. In severe cases; shock, pupils do not react to light, respiration irregular. Autopsy: hemorrhagic necrosis at bite; hemorrhages into muscles, bowel, central nervous system; blood incoagulable.	Guarded[33]	Yes	37
Marked local and regional edema, ecchymoses, anesthesia at site of bite, nausea and vomiting.	Fair	Yes	38
Similar to fer-de-lance. Autopsy: generalized visceral hemorrhages, cerebral hemorrhage, hemoglobinuric nephrosis.	Guarded	Yes	39
Presumably similar to poisoning by fer-de-lance.	Fair	Yes	40
Clinical and autopsy findings similar to fer-de-lance.	Guarded	Yes	41
Pain, edema, ecchymoses, weakness, sweating, vomiting, hemolytic anemia in severe cases.	Good	Yes	42
Similar to poisoning by N.A. copperhead, but more severe. Local necrosis more marked.	Fair	Yes	43
Local pain, edema and ecchymoses, dryness of mouth, vomiting, shock, hemolytic anemia. In severe cases: muscular twitching, paresthesia, speech difficulty, sensation of yellow vision, unconsciousness.	Guarded	Yes	44
Similar to cascabel, but less severe. Inadequate information.	Guarded	Yes	45
Usual local symptoms of Crotalus. Also thirst, abdominal pain, vomiting, diarrhea, dyspnea. In severe cases: excitement, hypertonicity of muscles, paresthesia, convulsions, cyanosis, respiratory failure, clouding of consciousness.	Fair	Yes	46
Similar to western diamondback but less severe.	Fair	Yes	47
Local pain, edema, vesication, pallor, vomiting, fever, restlessness, shock, anemia.	Fair	Yes	48
Similar to eastern diamondback but neurotoxic symptoms less marked. Profound shock in severe cases.	Guarded	Yes	49
Inadequate information. Presumably similar to prairie rattlesnake but less severe.	Fair	Yes	50
Local pain, edema and necrosis, minimal systemic reaction. Information meager, possibly unreliable.	Good (?)	Yes	51
Similar to fer-de-lance. Late death from CNS hemorrhage. Autopsy: massive subdural hemorrhage, dilated left heart, renal hemorrhage, cerebral edema.	Guarded	Yes	52
Local pain, ecchymoses, blistering, little systemic reaction.	Fair	Yes	53
Local pain and edema, minimal systemic reaction.	Good	Yes	54
Local pain, swelling and necrosis, pallor, weakness, rapid pulse, prolonged clotting time.[38]	Good	Yes	55
Local symptoms as with other Bothrops spp. Also headache, faintness, bleeding from gums.	Good	Yes	56

Considerable geographic and individual variation in toxicity exists, e.g., Ancistrodon contortrix, Bothrops jararacussu, B. neuwiedi, Crotalus terrificus in excess of 40%. /29/ Fangs front, movable, hollow; pit between eye and nostril; more than 80 species. /32/ Aggressive. /33/ Mortality about Pallas' pit viper (A. halys), S.E. Europe, across Asia to Japan. /39/ Arboreal.

AND BIOLOGICAL CHARACTERISTICS

Bufotoxin[2]		Bufotenines[3]				
Action or Effect[4]	Toxicity[5] mg/kg	Name (Proposed Formula)	Action or Effect	Cardiac Arrest[6]	Remarks	
Digitalis-like; emesis; systolic standstill of heart.	0.756 ±0.075	Alvarobufotenine ($C_{12}H_{18}O_2N_2$)	Oxytocic; slight pressor action; diastolic standstill of heart.	1:5000 dil.	Cholesterol and ergosterol present.	1
Digitalis-like; emesis; ventricular fibrillation.	0.406 ±0.012	Arenobufotenine A ($C_{12}H_{20}O_2N_2$) Arenobufotenine B ($C_{14}H_{18}O_2N_2$)	Oxytocic; slight pressor action.	1:5000 dil. 1:5000 dil.	Cholesterol and epinephrine present.	2
Emesis; ventricular fibrillation.	0.292 ±0.017	Valgarobufotenine ($C_{12}H_{18}O_2N_2$)	Oxytocic; marked pressor action.		Cholesterol and ergosterol present.	3
Emesis; vasopressor effect, followed by cardiac collapse, death in systole; prolongation of P-R interval.	0.359 ±0.024	Cinobufotenine ($C_{14}H_{16}ON_2$)	Oxytocic; miotic; intense, short vasopressor action; contraction of smooth muscle not inhibited by atropine.	1:10,000 dil.	Cholesterol, epinephrine, norepinephrine and bufotenidine present.	4
Persistent action; slight pressor action; emesis; ventricular fibrillation.	0.374 ±0.027	Gamabufotenine ($C_{12}H_{18}O_2N_2$)	Oxytocic; marked pressor action.	1:5000 dil.	Cholesterol, epinephrine, and bufotenidine present.	5
More emetic than bufagin.	0.417[10] ±0.022	Marinobufotenine ($C_{12}H_{14}O_2N_2$)	Oxytocic; little or no pressor action.	1:5000 dil.	Epinephrine, cholesterol, ergosterol, 5-hydroxy-tryptamine also present.	6
Ventricular systolic standstill.		Quercicobufotenine ($C_{12}H_{18}O_2N_2$)	Oxytocic; slight pressor action.		Cholesterol present (?).	7
Emesis; ventricular fibrillation.	0.477 ±0.026	Regularobufotenine	Oxytocic; marked pressor action.		Epinephrine present (4.3-5% of whole venom, 10.7 mg per animal).	8
Digitalis-like action.		Americobufotenine. ($C_{12}H_{18}O_2N_2$)	Oxytocic; marked pressor action.			9
		Vallicepbufotenine ($C_{11}H_{12}O_2N_2$)	Oxytocic; slight pressor action; decreased amplitude and arrest of heart contractions.	1:1000 dil.		10
Action similar to, but weaker than, that of viridobufagin.	0.270 ±0.012	Viridobufotenine A ($C_{12}H_{14}O_2N_2$)	Oxytocic; marked pressor action.	1:5000 dil.	Cholesterol and ergosterol present.	11
		Viridobufotenine B ($C_{12}H_{20}O_3N_2$)	Oxytocic; slight pressor action.	1:5000 dil.		
Emesis.	0.792 ±0.034	Powlerobufotenine ($C_{13}H_{20}O_2N_2$)	Oxytocic; marked pressor action; epinephrine-like action.	1:5000 dil.	Bufotenidine present.	12

ogin with one molecule of suberyl-arginine. /3/ The bufotenines are organic bases having an indole ring in the molecule. /4/ On cat. /5/ Mean curring in Bufo paracnemis (Argentina). /9/ Also reported as $C_{42}H_{64}O_{11}N_4$. /10/ Also reported as 0.43 and 0.49.

Protozoa

1 PARALYTIC SHELLFISH POISONING caused by ingestion of molluscs which have fed on toxic dinoflagellates.
Animal, Distribution. Dinoflagellates: (Gymnodinium brevis), Florida coast; (Gonyaulax catenella), U.S. Pacific coast, Gulf of Mexico; (G. tamarensis), Nova Scotia, Canadian Atlantic coast; (Pyrodinium phoneus), Belgium.
Symptoms, Findings. Symptoms may appear within 10 min after ingestion. Gastrointestinal and mental symptoms variable. Paresthesia of lips, tongue and fingertips followed by ataxia and muscular incoordination. Ascending paralysis. Death may occur from cardiovascular collapse or respiratory failure in 2-12 hr. Aphasia also reported. (See also Molluscs.)
Chemistry, Toxicology. Toxin is a potent alkaloid soluble in alcohol and water, insoluble in ether and chloroform. Loses stability but not necessarily toxicity in aqueous solution with pH and temperature increase. Poison not isolated; postulated empirical formula of hydrochloride: $C_9H_{17}N_2O_2(HCl)_2$. Purest preparation has toxicity of 4 mouse units per µg. MLD for man is probably 5-10 mg. Neurotoxin with both central and peripheral actions. Depresses cardio-inhibitory and vasomotor centers and conduction system of myocardium.

Porifera

2 SPONGE STING caused by contact.
Animal, Distribution. Brown sponge (Fibulia nolitangere), W. Indies; fire sponge (Tedania ignis), W. Indies; fire sponge (T. toxicalis), California coast.
Symptoms, Findings. Urticaria and pruritis with occasional swelling of affected areas.
Chemistry, Toxicology. Intraperitoneal injections of crude extracts of the animal lethal to mice. Kills aquarium animals.

Coelenterata

3 HYDROID STING caused by contact. Venom apparatus of cnidoblasts comprised of capsule, nematocyst and cnidocil. Toxin is introduced through the tubular filament of the nematocyst. Chemical and mechanical factors appear to be involved in the discharge of the nematocysts.
Animal, Distribution. False; or stinging; coral (Millepora alcicornis), eastern Florida, Malays, tropical seas.
Symptoms, Findings. Acute burning sensation on contact. Erythema, pustule formation and desquamation reported.
Chemistry, Toxicology. Not known.

4 PHYSALIA STING caused by contact with nematocyst-bearing tentacles.
Animal, Distribution. Portuguese-man-of-war (Physalia physalis), Florida, Hawaii, Australia, warm seas.
Symptoms, Findings. Intense burning pain following contact. Erythematous wheals with occasional numbness. Gastrointestinal and mental symptoms reported, also muscular weakness and pain sometimes followed by clonic contractions. Respiratory distress in severe cases; secondary shock may develop. Skin lesions persist for weeks. Fatal cases reported.
Chemistry, Toxicology. Tentacles yield hypnotoxin, an anesthetising substance, precipitated by alcohol, non-dialyzable, and destroyed by temperature above 55°C.

5 JELLYFISH STING caused by contact.
Animal, Distribution. Sea wasp (Chiropsalmus quadrigatus), Indian Ocean, Netherlands Indies, Australia; giant jellyfish (Cyanea capillata), north temperate and arctic seas; pink-fringed jellyfish (Dactylometra quinquecirrha), Florida coast, Philippines.
Symptoms, Findings. Symptoms similar to those provoked by Physalia; fatal cases reported from Chiropsalmus sting.
Chemistry, Toxicology. Medusa-congestin, an alcohol-precipitated toxin, has been isolated from certain jellyfish. Toxin has local effect on pilomotor muscles; causes spastic contractions. Hypersensitizes temperature perception organ in skin.

6 SEA ANEMONE STING caused by contact.
Animal, Distribution. Sea anemones: (Actinia equina), Black Sea; (Actinodendron alcyonoideum), Pacific coral reefs, Australia; (Sagartia elegans), Mediterranean and African Seas.
Symptoms, Findings. Stinging sensation on contact; may be followed by pruritis and edema. Severe cases may develop papules which occasionally ulcerate. Systemic symptoms and deaths reported. "Sponge fisherman's disease" thought to be caused by Sagartia.
Chemistry, Toxicology. Actinia toxin separated into two fractions: congestin and thalassin. Congestin is a water soluble, heat resistant, white crystalline substance that produces vomiting, diarrhea and visceral congestion. One-tenth g/kg animal produces death from respiratory paralysis. Thalassin is a water soluble, alcohol-precipitated crystal antagonistic to congestin. One-hundredth mg/kg animal causes intense scratching and sneezing in dogs. A curare-like fraction, tetramine, has been isolated from Actinia equina.

Molluscs

7 CONE SHELL STING caused by contact. Wounds inflicted by hollow teeth attached to long slender, tubular, fleshy proboscis connected to a venom gland.
Animal, Distribution. Cloth-of-gold shell (Conus auricus), S. Pacific; cone shell (C. geographus), S. Pacific, Japan, Australia; cone shell (C. marmoreus), S. Pacific; cone shell (C. tulipa), S. Pacific.
Symptoms, Findings. Sting results in intense burning pain often followed by numbness. Area about wound is cyanotic and swollen. Muscular incoordination, paresis or paralysis, mental confusion, visual disturbances and paresthesia reported. In severe cases, respiratory distress and cardiovascular collapse. Deaths reported in 3-5 hr.
Chemistry, Toxicology. Not known.

8 PARALYTIC SHELLFISH POISONING caused by ingestion of mollusks. (See Protozoa.)
Animal, Distribution. Razor clam (Ensis directus), New England coast; bar or surf clam (Mactra solidissima), New England coast; horse or red mussel(Modiolus modiolus), both N. American coasts, Europe; ocean mussel (Mytilus californianus), Pacific coast N. America; common or blue mussel (M. edulis), Europe, N. American coasts, New Zealand, S. Africa; butter clam (Saxidomus giganteus), Pacific coast N. America, Canada; butter clam (S. nuttalli), California coast.
Symptoms, Findings. (See Protozoa.)
Chemistry, Toxicology. (See Protozoa.)

9 VENERUPIN POISONING caused by ingestion.
Animal, Distribution. Venus shell (Tapes semidecussata), Japan.
Symptoms, Findings. Gastrointestinal upset.
Chemistry, Toxicology. Toxic principle, called venerupin, thought to be an amine. LD of purified poison is 0.25 mg for a 15 g mouse. Venerupin treated with acidulated ethanol becomes violently toxic to mice, resembling paralytic shellfish poisoning. Causes acute yellow or red atrophy of liver and hemorrhagic symptoms.

10 OCTOPUS BITE. Venom apparatus of anterior and posterior salivary glands, salivary ducts, buccal mass and beak. Bite is puncture-wound variety. Venom is secreted by posterior salivary gland.
Animal, Distribution. Octopuses: (Eledone moschata), Mediterranean Sea; (Octopus spoilyon), Pacific coast N. America; (O. macropus), Europe, Mediterranean and Red Seas, Indian Ocean, Malaysia, China, Japan and Australia; (O. vulgaris), warm seas.
Symptoms, Findings. Symptoms variable. Bite usually produces sharp throbbing pain, tingling and edema lasting few hours to several days.
Chemistry, Toxicology. Not known.

Annelida

11 WORM BITE.
Animal, Distribution. Bloodworm (Glycera dibranchiata), Caribbean Sea, N. Carolina to Massachusetts, Pacific coasts of Mexico and S. California.
Symptoms, Findings. Stinging pain, edema, increase localized skin temperature, pruritis for several hours.
Chemistry, Toxicology. Not known.

Arthropoda

12 KING CRAB POISONING caused by ingestion.
Animal, Distribution. King or horseshoe crabs: (Carcinoscorpius rotundicauda), estuaries of Malaya and Siam; (Tachypleus gigas), Japan, Malaya, India.[1]
Symptoms, Findings. Onset of symptoms in 10 min to ½ hour. Dizziness, nausea, vomiting, weakness, headache, paresthesia of lips and mouth, cardiac arrhythmia, drowsiness, possible paralysis of muscles of mastication and limbs. Death may occur in 1-6 hr. In non-fatal cases, recovery is prolonged.
Chemistry, Toxicology. Tissues contain powerful toxic alkaloid. Flesh and eggs of Carcinoscorpius can be fatal.

Echinodermata

13 STARFISH POISONING caused by contact.
Animal, Distribution. Common starfish (Crossaster papposus). N. Atlantic coasts of Europe and America.
Symptoms, Findings. All starfish are said to exude a poison which diffuses through water or alcohol; when large numbers are present, the liquid may cause a pruritic rash.
Chemistry, Toxicology. Nature of toxin unknown. Extracts injected into cats produce prostration and convulsions.

14 SEA URCHIN STING caused by contact. Venom is injected by pedicerous pedicellariae which are comprised of three spoon-shaped blades, each having a globular body and hook-like process. Venom glands are located under each of the blades.
Animal, Distribution. Sea urchins: (Toxopneustes pileolus), Malaya, Japan; (Sphaerechinus granularis), Mediterranean Sea, eastern Atlantic.[2]
Symptoms, Findings. Pedicellariae wounds produce severe pain, faintness, giddiness, dyspnea, paralysis of lips and tongue, relaxation of limbs. Drop in body temperature is usual in animals. Facial paralysis may persist 6 hr. Total paralysis and death from drowning reported.
Chemistry, Toxicology. Toxin resistant to high temperatures and evokes curare-like action. Depressed body temperature in animals. Exact nature of toxin unknown.

15 SEA CUCUMBER POISONING caused by contact.
Animal, Distribution. Sea cucumbers: (Actinopyga agassizi), British W. Indies; (Holothuria argus), Netherlands Indies, Australia, Polynesia; (H. forskali), Mediterranean Sea, southern coast of England.
Symptoms, Findings. Injection of extracts kills mice; when added to water extracts kill fish. Contact with organ of Cuvier may produce inflammation of skin, intense pain, and loss of sight.
Chemistry, Toxicology. Active toxic agent holothurin, located in the organ of Cuvier, water soluble, non-volatile, and heat stable; decolorizes Lugol's solution but not methylene blue; cannot be extracted or inactivated with acetone, ether or chloroform. One ounce of crude extract per 750 gallons of water kills fish in 23 min. Intraperitoneal injection lethal to mice.

Chordata

16 ELASMOBRANCH POISONING caused by ingestion.
Animal, Distribution. Cow shark (Hexanchus griseus), Atlantic and Pacific Oceans, Mediterranean Sea; cat shark (Scyliorhinus caniculus), Atlantic Ocean, Mediterranean Sea; smooth dogfish (Mustelus canis), Atlantic Ocean, Caribbean Sea; requiem or blue shark (Prionace glauca), warm and temperate seas; Greenland shark (Somniosus microcephalus), North Sea, North Atlantic Ocean; skate (Raja batis), S. Africa, Atlantic Ocean.
Symptoms, Findings. Onset may occur within ½-1 hr. Nausea, vomiting, abdominal pain, oily stools, pallor, headache, burning and tingling sensation of lips, tongue and throat, visual disturbances, pain and heaviness in limbs, chest pain, and itching; primary shock reported. Coma and death may occur several days after ingestion.
Chemistry, Toxicology. Artificial immunity to Greenland shark; is poison water soluble and resistant to cooking temperatures (less than 100°C).

17 BULLHEAD SHARK STING caused by contact. Venom secreted by the glandular epithelium in the posterior groove of the dorsal spines.
Animal, Distribution. Bullhead sharks: (Heterodontus francisci), California coast; (H. philippi), Australia, Japan.[3]
Symptoms, Findings. Intense pain, redness, edema, increase skin temperature.
Chemistry, Toxicology. Not known.

18 STINGRAY STING caused by contact. Venom apparatus of a bilaterally serrated, dentinal caudal spine enveloped in an integumentary sheath. Venom contained within tissues of the two ventrolateral grooves.
Animal, Distribution. Common stingray (Dasyatis pastinaca), European coasts; round stingray (Urobatis halleri), Pacific coast of southern N. America; spotted stingray (Aetobatis narinari), tropical Pacific, Atlantic and Indian Oceans.
Symptoms, Findings. Sting followed by intense pain often involving entire affected extremity. Wound edges ragged, localized discoloration and edema. Primary shock common; convulsions and paresthesia reported; death infrequent.
Chemistry, Toxicology. Action of crude extract on peripheral vascular system may be diphasic, the principal response being vasoconstriction. Large doses provoke auricular and ventricular standstill; may damage sino-auricular node. Chemical properties unknown.

19 RATFISH STING caused by contact. Venom secreted by epithelium of the integumentary sheath of the dorsal spine. Greatest concentration of venom tissue in the interdentate depression on posterior aspect of spine.
Animal, Distribution. Ratfish (Chimaera monstrosa), Atlantic Ocean off Portugal and northern U.S.; Pacific ratfish (Hydrolagus colliei), Pacific coast of N. America.
Symptoms, Findings. Intense pain and deaths reported for Chimaera. Erythema and mild, dull ache lasting several minutes reported for Hydrolagus.
Chemistry, Toxicology. One ml of crude extract kills mice in 24-54 hr.

20 TETRAODON POISONING caused by ingestion.
Animal, Distribution. Sharp-nosed puffer (Canthigaster margaritatus), Red Sea, E. Africa, Netherlands Indies, China, Melanesia, Micronesia, Polynesia; sharp-nosed puffer (C. rivulatus), Japan, Hawaiian islands; puffer (Colomesus psittacus), rivers of Guiana, northern Brazil, W. Indies; puffer (Chilomycterus spinosus), W. Indies, Brazil, S. Africa; puffer (Diodon holacanthus), tropical Pacific, Atlantic and Indian Oceans; tetrodon of the Cape (Amblyrhynchotes honckenii), S. Africa, Indo-Pacific; puffer (Fugu basilewskiamus), northern China, northwestern Korea; puffer (F. chrysops), Pacific coast of central Japan; puffer (F. niphobles), Japan; puffer (F. ocellatus), China, Japan, Philippine Islands; puffer (F. pardalis), China, Japan; puffer (F. pseudomus), East China Sea and Yellow Sea; puffer (F. rubripes), China to Korea, Sea of Japan, Pacific coast of Japan; puffer (F. stictonotus), southern Korea, East China Sea, Japan; puffer (F. vermicularis), East China Sea, Japan; puffer (F. xanthopterus), China, Korea, southern Japan; puffer (Lagocephalus laevigtus inermis), eastern Africa, tropical Indian Ocean, Australia, East China Sea, southern Japan; puffer (L. lunaris), Red Sea, southern and eastern Africa, India to Australia, China, Japan; puffer (L. sceleratus), east coast Africa to Philippine Islands, southern Japan, Australia, Tahiti; puffer (Sphoeroides annulatus), California to Peru, Galapagos Islands; puffer (S. maculatus), Atlantic coast, U.S. to Guiana; puffer (S. spengleri), Texas, Florida, W. Indies, Brazil, Canary Islands, west coast Africa; puffer (Torquigener hamiltonii), Australia, Melanesia, Polynesia; sunfish (Mola mola), temperate and tropical seas; puffer (Arothron aerostaticus), Red Sea, eastern Africa, Netherlands Indies, Australia, Guam, Japan, Tahiti; puffer (A. hispidus and immaculatus), Red Sea, S. Africa to southern Japan, Australia, Melanesia, Micronesia, Polynesia, Panama; puffer (Tetraodon lineatus), rivers of northern and western Africa.
Symptoms, Findings. Onset within 30 min after ingestion. Numbness of lips, tongue, fingertips and toes; nausea, vomiting, headache, dizziness, weakness, dyspnea; occasional complete paralysis and loss of speech reported; coma and death may occur within 1-24 hr as a result of respiratory paralysis.
Chemistry, Toxicology. Postulated formula for tetrodotoxin: $C_{16}H_{31}NO_{16}$; soluble in water; MLD for rabbits is 3.0-4.0 g/kg. Spheroidine: $C_{12}H_{17}O_{10}N_3$; insoluble in water; MLD for mice, 0.013-0.014 µg. Only a few Japanese puffers studied. It is assumed that all puffers contain same toxin.

/1/ Common sand crab (Emerita analoga), Pacific coast, Oregon to Mexico; contains paralytic shellfish poison varying in toxicity, depending on nearby mussels. /2/ Also sea urchins: (Asthenosoma varium, Diadema antillarum, D. setosum, Echinothrix spp, Echinus acrus, Paracentrotus lividus, Salmacis sphaeroides); toxin in spines; nature unknown. /3/ Also DOGFISH STING. Spiny dogfish (Squalus acanthias), temperate waters of N. and S. hemispheres.

Chordata (concluded)

21 CIGUATERA POISONING caused by ingestion.
Animal, Distribution. Surgeonfish (Acanthurus triostegus), tropical Pacific; ladyfish (Albula vulpes), tropical Pacific; left-eyed flounder (Bothus mancus), tropical Pacific; pompano (Caranx latus), W. Indies, South Africa, Australia; pompano (C. melampygus), Red Sea, Indian Ocean, central Pacific; herring (Clupanodon thrissa), W. Indies, Indian Ocean, Japan; anchovy (Engraulis japonica), Japan; wrasse (Epibulus insidiator), tropical Pacific; wrasse (Cheilinus fasciatus), Red Sea to tropical Pacific, Japan; snapper (Lutjanus vaigiensis), Indian Ocean and tropical Pacific; snapper (L. bohar), Red Sea, Indian Ocean, tropical Pacific, Japan; goatfish(Mulloidichthys samoensis), tropical Pacific; damselfish (Abudefduf sexfasciatus), tropical Pacific; parrot fish (Scarus microrhinos), Indian Ocean, tropical Pacific; bass (Epinephelus fuscoguttatus), Red Sea, Indian Ocean, tropical Pacific; bass (Variola louti), Red Sea, Indian Ocean, tropical Pacific; squirretail (Tetragonurus cuvieri), Mediterranean Sea, Atlantic and Pacific Oceans.
Symptoms, Findings. Onset may be immediate but usually within 30 hr. Tingling, numbness, malaise, chills, fever, headache, sweating, pruritus diarrhea, prostration, metallic taste, generalized motor incoordination, weakness and myalgia common. Sensory disturbances (perversion of heat and cold): convulsions and paralysis reported. About 2-3% of cases fatal. Complete recovery may take months.
Chemistry, Toxicology. Not known.

22 GYMNOTHORAX POISONING caused by ingestion.
Animal, Distribution. Moray eels: (Gymnothorax eurostus, G. flavimarginatus, G. javanicus, G. meleagris, G. pictus, G. peteill, G. undulatus), Red Sea, Indian Ocean, tropical Pacific.
Symptoms, Findings. Onset 20 min to 8 hr with tingling, numbness, vomiting, respiratory distress, laryngeal spasm and paralysis, motor incoordination, clonic and tonic convulsions; abnormal deep and superficial reflexes reported. Coma may develop, lasting 2-10 da; mortality about 10%. Acute symptoms usually subside within 10 da.
Chemistry, Toxicology. May be small molecular substance. One ml of crude extract injected intraperitoneally into mice produces death in 16 min to 24 hr.

23 SCOMBROID POISONING caused by ingestion.
Animal, Distribution. Mackerel (Scomber japonicus), Pacific, Atlantic, Indian Oceans, Mediterranean and Red Seas; skipjack(Katsuwonus pelamis), cosmopolitan; tuna (Thunnus thynnus); cosmopolitan.
Symptoms, Findings. Histamine-like symptoms: headache, flushing, congestion of soft tissues of eyes, nausea, vomiting, urticaria, and erythema. Recovery within 12 hr.
Chemistry, Toxicology. Thought to be histamine or histamine-like substance. Exact mechanism of production and chemical structure unknown.

24 SCORPION FISH STING caused by contact. Venom apparatus of the dorsal, ventral and anal stings. Primary sites of venom production in the glandular grooves of the stings.
Animal, Distribution. Bullrout (Notesthes robusta), Australia; thread-finned zebrafish (Pterois antennata), all tropical and temperate seas; tiger fish (P. lunulata), Japan, Banka Islands; zebrafish (P. volitans), E. Africa to Australia, Japan; lionfish (Scorpaena grandicornis), all seas; hogfish (S. porcus), Mediterranean Sea, Atlantic Ocean; scorpion fish (S. scrofa), Mediterranean Sea, Atlantic Ocean; lumpfish (Inimicus didactylus), Philippines, Malaya, Johore Straits; stonefish (I. japonicus), Sea of Japan, China Sea; stonefish (Minous monodactylus), South Seas, China, Japan; stonefish (Synancea horrida), Red Sea, coasts of Africa, India, Malaya, Indo-Pacific, Australia, New Zealand; stonefish (S. verrucosa), Red Sea, coasts of Africa and India, Netherlands Indies, Australia, tropical Indo-Pacific, Marshalls, Polynesia.
Symptoms, Findings. Localized pain, pallor about wound, diarrhea, vomiting. Dyspnea, coma and fatalities reported.
Chemistry, Toxicology. Not known.

25 WEEVERFISH STING caused by contact. Venom apparatus of opercular and dorsal stings. Venom gland located within glandular grooves of the sting.
Animal, Distribution. Weever (Trachinus draco), European seas, Australia, Chilean seas; (T. radiatus), Mediterranean Sea; (T. vipera), European seas.
Symptoms, Findings. Intense shooting pain, redness and edema of affected part, vomiting, diuresis and diarrhea.
Chemistry, Toxicology. Two or three drops of venom injected intravenously into rabbit produce death in 4-10 min. Venom thought to contain both neurotoxic and hemotoxic fractions.

26 TOADFISH STING caused by contact. Venom apparatus of the opercular and dorsal stings. Venom produced by sac-like glands at base of stings.
Animal, Distribution. Grunting toadfish (Batrachus grunniens), W. Indies, tropical waters; toadfish (Opsanus tau), waters of N. America; toadfish (Thalassophryne dowi), Pacific coast of Panama, tropical and south temperate America; toadfish (T. maculosa), east coast of America; lumpfish (T. reticulata) Panama, Brazil.
Symptoms, Findings. Severe localized pain; convulsions reported. Seldom serious.
Chemistry, Toxicology. Not known.

27 CATFISH STING caused by contact. Venom apparatus of dorsal and pectoral stings, and axillary venom glands. Venom glands in the integumentary sheaths surrounding the spines. Axillary gland located under skin beneath posthumeral process of cleithrum and opens to outside by pore.
Animal, Distribution. Madtoms (Noturus spp), rivers of N. and S. America; Madtoms (Schilbeodes spp), rivers of N. and S. America; sea catfish (Galeichthys felis), coasts of southeastern U.S.; (Heteropneustes fossilis), India, Burma, Ceylon, Indo-China, swamps, marshes, muddy rivers; (Ictalurus catus), rivers of northestern America, Italy; (Plotosus lineatus), throughout Indo-Pacific region.
Symptom, Findings. Stinging pain either localized or radiating through limb, usually subsides within 30 min. Area becomes ischemic, redness and edema may follow. In severe cases massive edema and numbness involving entire limb often accompanied by lymphadenopathy. Primary shock reported. Recovery may take weeks.
Chemistry, Toxicology. Not known.

28 SURGEONFISH STING caused by contact. Caudal penduncular spine inflicts wound.
Animal, Distribution. Surgeonfish, lancet fish (Acanthurus hepatus), Atlantic Ocean to W. indies.
Symptoms, Findings. Sharp pain which may last several hours.
Chemistry, Toxicology. Not known.

29 DRAGONET STING caused by contact. Venom apparatus of venom glands in connection with spines. (See Weeverfish.)
Animal, Distribution. Dragonet (Callionymus lyra), coast of France, tropical zones.
Symptoms, Findings. Sharp stinging pain.
Chemistry, Toxicology. Not known.

30 TURTLE POISONING caused by ingestion.
Animal, Distribution. Hawksbill sea turtle (Eretmochelys imbricata), Arabia, Malay Peninsula and Archipelago, Australia, Formosa, Samoa, Guinea, Bahamas, Guatemala; hawksbill (Chelonia japonica) Philippines; leatherback (Dermochelys coriacea), Cape of Good Hope, Indian Ocean, New Zealand, Solomons.
Symptoms, Findings. Onset almost immediate to one week, with nausea, vomiting, diarrhea, weakness and sore lips and throat. Hallucinations, coma and death may occur within 12 hr after ingestion.
Chemistry, Toxicology. Not known.

31 PORPOISE POISONING caused by ingestion.
Animal, Distribution. Porpoise (unidentified sp), Yangtze region of China. Chinese rivers. Not poisonous in open seas.
Symptoms, Findings. Onset almost immediate. Severe pain, numbness and paralysis of extremities, cyanosis, swelling of abdomen, salivation, and rapid death. Many fatal cases reported, especially in spring. Blood, liver, fat and eyes are reported most toxic.
Chemistry, Toxicology. Not known.

	Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
1	Amanita, deadly (Amanita phalloides) [Entire fungus] Europe, N. America	Amanita-toxin (amanitin) formerly reported as phallin. Fungus also contains amanita-hemolysin, possibly a factor in poisoning by the raw mushroom.	After 6-15 hr: Abdominal pain; vomiting; diarrhea; intense thirst; recurrent drowsiness; respiratory, circulatory depression; delirium; sometimes convulsions; jaundice, hepatitis; renal disturbances; coma; death from heart failure.	One of the most deadly of fungi with a mortality of about 90%; cause of 90% of "mushroom deaths" in U.S. Genus contains other equally poisonous mushrooms and some edible species.
2	Autumn crocus (Colchicum autumnale) [Entire plant; principally corms, seeds] U.S., England, Europe, N. Africa	Colchicine.	Man: Burning in throat; 6-8 hr later a feeling of suffocation, oppression in chest, difficult swallowing; vomiting; diarrhea; colic; tenesmus; giddiness; weakness in legs; arthralgia; cyanosis; labored breathing; convulsions; death from respiratory exhaustion in 7-36 hr; consciousness preserved to end. Other animals: Nausea, vomiting; colic; diarrhea; hematuria; depression; unconsciousness; paralysis; mydriasis; profuse perspiration. Death in 1-3 days.	Colchicine arrests mitotic division of cells. Effects in relief of gout may be dramatic.
3	Belladonna[1] (Atropa belladonna) [Entire plant; especially seeds, roots, leaves] Europe, Asia, eastern U.S.	Chiefly hyoscyamine, atropine, other solanaceous alkaloids.	Man, acute: Dryness of skin, mouth, throat; difficulty in swallowing; flushing of face; cyanosis; mydriasis; nausea; vomiting; constipation. Slurred speech; giddiness; stupor; coma; rapid, weak pulse; fever; death from asphyxia, heart failure. Man, chronic: Erythema, urticaria, vesicular eruptions; slurred speech; mydriasis; glaucoma; muscular tremors or twitchings. Sudden withdrawal causes nausea, salivation, perspiration. Cattle: Mydriasis; constipation; rapid pulse; labored breathing; frenzy; paralysis.	Yields belladonna preparations. Fruits most often responsible for poisoning in man.
4	Castor bean (Ricinus communis) [Seeds] Primarily tropical Africa; U.S., tropics and subtropics	Ricin or phytotoxin; ricinine.	Man: Burning in mouth, throat and stomach; vomiting; diarrhea; thirst; rapid, then faint pulse; cramps of abdomen, legs; convulsions; shallow respirations. Other animals: Hemorrhagic enteritis; staggering; dulled vision; heart weakness; bloating; paralysis; convulsions; fever; shivering; coma; death in 1-3 days.	Seeds yield castor oil. 2 or 3 seeds may be fatal to child. Ricin not extracted in oil.
5	Chinaberry (Melia azedarach) [Fruit (pulp only), bark, flowers] S.W. Asia, South Africa, tropical America, southern U.S.	Azadirin (margosine), possibly an alkaloid, affecting central nervous system.	Man: Leaf poisoning produces stomatitis, decrease in urine formation; violent, bloody vomiting. Fruit poisoning results in irregular breathing, signs of suffocation; complete paralysis. Other animals (especially swine): Vomiting; colic; diarrhea, labored breathing; convulsions or paralysis; death by asphyxia.	Roots, bark, leaves, flowers and fruit used for stupefying fish. Seeds yield oil of azedarach.
6	Chokecherry and other wild cherries (Prunus spp) [Leaves, especially when wilted; bark, seeds] Primarily northern hemisphere; Orient	Hydrocyanic acid is formed by action of enzymes upon amygdalin (?) or prunasin.	Animals: Uneasiness, staggering; falling; convulsions; labored breathing; bloating; death.	Frequent cause of fatal poisoning of livestock.
7	Christmas rose (Helleborus niger) [Rootstock, leaves] Principally Europe	Helleborin, helleborein, hellebrin.	Man, externally: Severe dermatitis in some individuals. Man, internally: Violent inflammation of mucous membranes of stomach, intestines; vomiting; dizziness; convulsions; sometimes death. Digitalis-like effect on heart.	Cultivated in flower gardens. Rootstock formerly an official drug.
8	Coca (Erythroxylum coca) [Leaves] Northern S. America; tropics of both hemispheres	Cocaine, other alkaloids.	General central nervous system stimulation followed by depression; numbness of tongue, paralysis of respiratory centers; cyanosis; shallow, irregular breathing; often sudden death from asphyxia.	Leaves commonly chewed as a stimulant by Indians of Peru and Bolivia. Cocaine used as a local anesthetic.
9	Corn-cockle (Agrostemma githago) [Seeds] Europe, Canada, U.S.	Githagin, agrostemmic acid (saponins).	Man: Irritation of digestive tract; vomiting; headache; vertigo, diarrhea; depressed breathing; sharp pains in spine; difficult locomotion; sometimes coma, death. Horses and cattle: Colic; diarrhea, muscular tremors; rigidity; coma, death. 0.25-1 lb per 100 lb live weight fatal.	Milled seeds sometimes present in wheat flour. Frequent ingestion of small amounts results in chronic githagism.
10	Croton, purging (Croton tiglium) [Roots, leaves, bark, seeds] Southern Asia, East Indies, Pacific Islands, Africa	Crotin, croton resin.	Externally: Croton oil is a skin-irritant, causing reddening, swelling, pustules. Smoke from burning wood inflames the eyes. Internally: Vomiting, drastic purging; possibly collapse and death.	Yields croton oil, formerly a human and veterinary purgative, lubricant for fine machinery.
11	Curare (Strychnos toxifera) [Bark, roots; not extremely toxic by mouth] Central America, northern S. America	Tertiary bases: curine, α-chondrocurine, α-isochondrodendrine, and α-isochondrodendrine dimethyiether. Quaternary salts: α-tubocurarine chloride, α-chondrocurine dimethoiodide, and α-tubocurarine chloride and others.	Haziness of vision; relaxation of facial muscles; inability to raise head; loss of muscular contraction in arm and leg; depressant effects on the muscles of respiration, muscle nerve end-plate paralysis.	Source of curare, one of the most potent poisons known. Tubocurarine chloride (U.S.P.) now used as a skeletal muscle relaxant in shock therapy, and as a diagnostic aid.
12	Death camass (Zigadenus spp) [Leaves, stems, flowers, bulb] Northern hemisphere, especially western U.S.	Zygadenine, similar to veratrine and cevadine in action.	Animals: Salivation; vomiting; lowered temperature; staggering or collapse; labored breathing; paralysis; possibly coma, death.	Frequent cause of fatal poisoning of livestock. Children occasionally poisoned by eating bulb.

/1/ Henbane (Hyoscyamus niger), which yields scopolamine, hyoscyamine, atropine, and other alkaloids, has similar signs and symptoms.

	Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
13	Ergot (Claviceps purpurea) [Sclerotium] Europe, Asia, Australia, N. America	Ergotoxine, ergotamine, ergonovine, and others.	Man, acute: Vomiting; diarrhea; respiratory difficulties; visual, motor disturbances; followed by convulsions, lowered blood pressure, shallow respiration, unconsciousness. In pregnancy, possibly uterine hemorrhage, abortion, peripheral gangrene. Man, chronic: Convulsive type -- vomiting; itching; paresthesia; analgesia of extremities; anorexia or uncontrollable hunger; diarrhea; muscle contracture; delirium; sometimes a tabes-like complex. Gangrenous type -- pustules may form; limbs swell, become hot, gangrene may follow. Cattle: Gastrointestinal irritation; gangrene of extremities; uterine contractions; nervous disturbances.	Occurs on wheat, oats, barley, rye, and other grasses; cause of many cases of poisoning (ergotism) in man and livestock.
14	Foxglove (Digitalis purpurea, D. lanata) [Entire plant, especially seeds, leaves] From western Europe; widely distributed.	Diacetyldigitaloid A and B io D. purpurea. Digitalinid A, B, C, io D. lanata.	Anorexia; nausea; vomiting; slow, pronounced pulse in early stages; cardiac arrhythmias; diarrhea; abdominal pain; headache; fatigue; drowsiness; convulsions; rapid, irregular pulse; death in severe cases.	Digitalis and derivatives used in cardiovascular therapy. D. purpurea common in flower gardens.
15	Grass-pea (Lathyrus sativus) [Seeds, mature plant] Southern Europe, Asia, southern U.S.	Alkaloids.	Man: Sudden weakness in legs from effect on spinal cord. Further ingestion may cause leg paralysis. Animals: Similar, plus asphyxia. Cattle evidence constipation, weak pulse, numbness of skin.	Used as food and fodder but causes many cases of lathyrism in man and livestock.
16	Groundsel (Senecio spp) [Entire plant, especially seeds] World-wide.	Senecifoline, senecifolidine, retrorsine, seneciphyline, jacobine.	Man: Abdominal pain; vomiting; ascites; enlarged liver; emaciation; bloody diarrhea. Generally fatal in the absence of early treatment. If not immediately fatal, liver damage may bring about subsequent death. Grazing animals: Inappetence; emaciation; staggering; colic; unconsciousness; death.	Seeds of various species in harvested grain considered responsible for "bread poisoning." Senecio poisoning common in livestock.
17	Hellebore, American white (Veratrum viride) [Entire plant] Canada, U.S.	Protoveratrine, germerioe, jervine, and others.	Man: Vomiting; abdominal pain; muscular weakness; spasms; possibly convulsions; rapid pulse; shallow breathing; semi-consciousness; death from asphyxia.	This and related species yield veratrum, a therapeutic agent for hypertension.
18	Hemp, marijuana (Cannabis sativa) [Upper leaves, flower bracts of female plants] Temp. Asia, Europe, U.S., Mexico, Panama	Cannabinene, tetanocannabine, cannabinol.	Man: Exaltation; inebriety; confusion; followed by central nervous system depression. Prolonged addiction may produce dullness or manis; in rare cases death from cardiac depression.	Dried leaves and bracts smoked by marijuana addicts; seeds harmless.
19	Larkspur (Delphinium spp) [Seeds, leaves; to a lesser degree, roots] North temperate regions, including western U.S.	Delphinine, delphinoidine, delphisine, staphisagroine.	Man: Burning, inflammation of mouth and pharynx; lowered blood pressure; nausea; abdominal pain; labored respiration; itching; cyanosis. Animals: Inappetence; uneasiness; staggering; constipation; nausea; bloating.	Second to locoweed (q.v.) in causing fatalities among livestock.
20	Lead-tree (Leucaena glauca) [Leaves (especially immature), bark, roots] Southern U.S., tropics	Mimosine (leucenol).	Horses, mules and donkeys: Alopecia of manes and tails; possibly deformation, loss of hoofs. Swine: Total alopecia; impaired vision; emaciation; various degrees of paralysis; respiratory failure.	A fodder plant for cattle, sheep, goats (immune to toxic action). Seeds used as coffee substitute.
21	Locoweed (Astragalus spp) [Fresh plant] Northern hemisphere	Selenium; locoice in some species.	Horses and cattle: Dullness, weakness; irregularity in behavior, impaired vision; edema of eyelids; loss of muscular control, depraved appetite; emaciation; starvation, death. Sheep: Above symptoms, with possibly blindness.	Hazard to livestock industry of the U.S.; toxicity varies with locality.
22	Lupine (Lupinus spp) [Pods, leaves, especially seeds] Temperate regions.	European spp: lctrogen (lupinotoxin); American spp: sparteine (lupinidine), lupinine.	European lupinosis, chronic: Anemia; cachexia. Acute: Fever; general icterus; coma; paralysis; constipation followed by hemorrhagic diarrhoea; swelling of ears, eyelids, lips, nose. American lupinosis, sheep: Frothing at mouth; dyspnea; frenzied actions; nausea; bloating; coma, possibly death.	Toxicity of lupines varies with season and location; some species are harmless. Many livestock fatalities in Europe and U.S. attributed to lupines.
23	Manchineel (Hippomane mancinella) [Milky sap] Florida, W. Indies, Central America, northern S. America	Physostigmine or a similar alkaloid, plus a sapogenin.	Man, externally: Severe burning of skin, swelling; possibly hemorrhage in eyes; temporary blindness from sap. Man, internally: First causes gastroenteritis which may be fatal. Ulceration of intestinal tract proceeds slowly.	Apparently more toxic in summer than in winter. Sap used as arrow poison. Smoke from burning wood toxic.
24	Manioc (Manihot esculenta) [Roots; mature leaves, stems, fruit] Tropics	Phaseolunatin	Man and livestock: Rapid, labored breathing; rapid, irregular, weak pulse; twitching; staggering; spasms of neck, legs; convulsions; mydriasis; coma; death from respiratory paralysis.	Cultivated for starch from which tapioca is made.
25	Metel (Datura metel) [Entire plant] India; tropics	Scopolamine, hyoscyamine, atropine.	Man: Mydriasis, drowsiness, thirst, bitter burning sensation in mouth, impaired vision; delirium. Exhaustion, coma, death, in extreme cases. Fatal poisoning usually results in loss of memory, mental confusion.	Used medicinally in Far East, employed criminally for narcotic effect on victims.
26	Monkshood (Aconitum napellus) [Roots, leaves, flowers, seeds] Europe, Asia, Canada, northeastern U.S.	Aconitine, pseracconitine, aconine, napelline, and others.	Moderate doses: Tingling, burning sensation in tongue, throat, skin; great restlessness; dyspnea; slow pulse, muscular weakness; incoordination; cold, livid skin; pupillary constriction, followed by dilation; vomiting; diarrhea; convulsions; possibly death in 1-8 hr by respiratory or cardiac paralysis.	Young leaves have been eaten by mistake for parsley and the roots for horseradish.
27	Mountain-laurel (Kalmia latifolia) Sheep-laurel (K. angustifolia) [Entire plant, except wood] Canada, northeastern U.S., Pacific Coast	Andromedotoxin.	Animals (usually sheep): Salivation; flow of tears; secretions from nose; frothing at mouth; impaired vision or blindness; dizziness; irregular respiration; vomiting; convulsions, followed by paralysis of limbs, coma, death. Man: Similar to above, plus pain in head, sweating, tingling of skin.	Frequent cause of fatal poisoning of livestock, especially sheep.

	Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
28	Nightshade, black (Solanum nigrum) [Entire plant, unripe fruit] World-wide	Solanine, saponin.	Man: Vomiting; diarrhea; rapid pulse; fever; sweating; dizziness; mydriasis; disturbed speech, sight; hallucinations. Death from heart failure or respiratory paralysis. Other animals: Nervous form -- narcosis; paralysis. Gastric form -- salivation; vomiting; bloating; diarrhea. Exanthematous form -- vesicular exanthems on legs, udder, scrotum, neck; conjunctivitis.	
29	Oleander (Nerium oleander) [Leaves, bark, roots, flowers] Tropics, subtropics	Nerlin, oleandrin.	Man: Vomiting; slow, irregular pulse; bloody diarrhea; death from cardiac or respiratory paralysis. Other animals: Similar to above, plus sweating, gnashing of teeth, groaning, sometimes polyuria.	Smoke from burning green plants can cause poisoning. Meat roasted on skewers of oleander wood, or food stirred with oleander sticks, becomes fatally poisonous. Honey made from the nectar possibly toxic.
30	Physic nut (Jatropha curcas) [Seeds, milky sap] Tropics	Curcin.	Man: Burning in throat; bloating; dizziness; vomiting; diarrhea; drowsiness; possibly dysuria, mydriasis; severe leg cramps; deafness. Violent purgative action often fatal to children. Other animals: Hemorrhagic enteritis; staggering; dull vision; mydriasis; bloating; paralysis; somnolence; convulsions; fever; shivering; coma; death in 1-3 days in acute cases.	Sap used as a fish poison.
31	Poison hemlock (Conium maculatum) [Fruit; stems, leaves, root] Europe, Asia, Africa, N. America	Coniine, conhydrine, methyleoniine, coniceine.	Man: Muscular weakness; often blindness; paralysis of extremities; death from respiratory paralysis. Cattle: Inappetence; salivation; bloating; muscular weakness; coma. Horses: Nausea; grinding of teeth; rapid, labored respiration; paralysis; death from respiratory failure.	Leaves more toxic when plant is flowering; root less toxic in spring.
32	Poison ivy (Rhus toxicodendron)[2] [Entire plant] N. America	Urushiol, toxicodendrol, or toxicodendrin.	Man: Skin irritation, swelling, blisters, extreme discomfort. Sometimes fatal to children.	Smoke from burning plant toxic.
33	Poison wood (Metopium toxiferum) [Entire plant, especially sap] Southern Florida, W. Indies	Probably similar to poison ivy.	Externally: Dermatitis similar to that caused by poison ivy. Blistering may continue for weeks, readily spreading from one area to another; may be accompanied by intense itching, burning.	Smoke from burning wood highly irritating.
34	Pokeweed (Phytolaca americana) [Entire plant, especially root] Eastern and southern U.S.	Saponin and a toxic resin-like material.	Vomiting; purging; spasms, sometimes convulsions; death from respiratory paralysis.	Young shoots edible if well cooked.
35	Spurge (Euphorbia spp) [Milky sap] World-wide	Euphorbon, euphorboresene, and an acrid substance.	Man, externally: Dermatitis; eye-irritation, temporary blindness. Man, internally: Swelling around mouth, eyes; burning in mouth, throat; sneezing; vomiting; diarrhea; fainting; death. Other animals, externally: Blistering of skin, loss of hair. Other animals, internally: Weakness; collapse; scours; death.	Euphorbium derived from E. resinifera formerly used medicinally, now employed in paint as a protectant. Severe dermatitis observed from sap of poinsettia (E. pulcherrima).
36	Strophanthus (Strophanthus spp) [Seeds, bark] Tropical Africa, southern Florida, tropical America	Strophanthin.	Vomiting; slow, irregular pulse; blurred vision; delirium; death from circulatory failure of cardiac origin. Effect on heart similar to that of digitalis.	Arrow-poisons from several species. S. sarmentosus is a possible source of cortisone.
37	Strychnine tree (Strychnos nux-vomica) [Seeds, leaves, bark, wood, flowers] India, Hawaii	Strychnine, brucine.	Action on spinal cord causes excessive reflex irritability, followed by rapid tonic convulsions with intermissions of exhaustion and sweating; extreme muscular rigidity, asphyxia; death. Mind not affected.	Strychnine formerly used as stimulant and tonic.
38	Thevetia (Thevetia peruviana) [Leaves, seeds, bark, milky sap] Tropics	Thevetin.	Externally: Contact with sap may inflame and blister skin. Internally: Vomiting; high blood pressure; erratic heart beat; death from asphyxiation, sudden cardiac paralysis.	Seeds used as fish poison.
39	Thorn apple (cocklebur) (Datura stramonium) [Entire plant (including flowers, nectar), especially seeds] Tropics; N. America	Scopolamine, hyoscyamine, atropine.	Man: Headache; nausea; vertigo; thirst; dry, burning sensation in skin; mydriasis; loss of muscular control. Acute poisoning results in mania, convulsions, death. Cattle: Mydriasis; suspension of secretions or diarrhea; rapid heart action; paralysis; death from asphyxia. 10-15 oz of plant fatal. Swine: Convulsive twitching.	Children often poisoned by eating seeds and pods.
40	Upas tree (Antiaris toxicaria) [Milky sap] Southern Asia, E. Indies	Antiarin (α-, β-)	Externally: Skin irritation, blistering, swelling. Internally: Vomiting; convulsions; death.	One of the principal arrow-poisons of natives of E. Indies, southern Asia. Cloth made from the bark causes intolerable itching if sap (latex) is not thoroughly eliminated. More potent than digitalis in effect on heart.
41	Water hemlock (Cicuta maculata and related spp) [Primarily roots] North temperate regions	Cicutoxin.	Man and other animals: Abdominal pain; nausea; vomiting; diarrhea; mydriasis; labored breathing; foaming at mouth; weak, rapid pulse; epileptoid convulsions; death from respiratory failure.	Genus includes the most poisonous plants in the U.S.
42	Wild yam (Dioscorea hispida) [Entire plant, tubers] Southern Asia, E. Indies, Pacific Islands	Dioscoreine.	Discomfort, then burning, in throat; giddiness; vomiting of blood; suffocation; drowsiness; exhaustion.	Eating raw tubers a frequent cause of death in Philippines.

[2] Data applicable also to poison sumac (R. vernix).

Information regarding properties of salts is enclosed in brackets. Remarks when not bracketed may refer to alkaloids (base or B) or to salts, or to both.

	Alkaloids [Salts][1]	Botanical Source	Geographical Source	Properties[2]	Solubility[2]	Remarks[3]
1	Aconitine $C_{34}H_{49}NO_{11}$	Aconitum napellus (root).	Europe, Asia.	MP = 204; $(a)_D$ =+17.3° in chl.	s. chl., bz., al., eth.; i.w.	One of several isomers in aconite root. Acts peripherally and centrally on nervous system; highly toxic; relieves neuralgia, toothache; depresses heart; lowers blood pressure; causes smarting, tingling of skin, prickling in throat.
2	Apomorphine $C_{17}H_{17}NO_2$ [B·HCl·$\frac{1}{2}$ H_2O]	Morphine.		[$(a)_D$ = -48° in w.]	[s. w.1:50.]	B and salt oxidize readily in air. Stimulates medullary chemoreceptor trigger zone to produce emesis; CNS depressant.
3	Arecoline $C_8H_{13}NO_2$ [B·HBr]	Areca catechu (nut).	Pacific islands, India, E.Africa.	BP = 209; opt. inactive; [MP = 169-171].	s.w., al., eth., chl.; [s. w.1:1].	Parasympathetic stimulant; sialogogue diaphoretic; anthelmintic.
4	Atropine (sa.-Hyoscyamine) $C_{17}H_{23}NO_3$ [B_2·H_2SO_4·$4H_2O$]	Atropa belladonna (leaf, root), also synthetic.	Europe.	MP = 118; $(a)_D$ = 0°; [MP = 190-194; $(a)_D$ =O°].	s.w. 1:455, al. 1:2, glyc., eth., bz., chl.; [s.w.1:0.4, al.1:5, al.s.chl., eth.].	Parasympatholytic: mydriatic, speeds heart, relaxes gut, causes vasodilation, inhibits secretions; also CNS stimulant.
5	Berberine $C_{20}H_{19}O_4N$·$\frac{1}{2}$ H_2O [$C_{20}H_{18}O_4N^+HSO_4^-$]	Barberry (bark) (Berberis vulgaris, B. asiatica).	Europe, India, N. America.	Loses water above 100°C; d. about 160°C.	s.w., al.; sl. s. acet., bz., eth., chl.; [s.w.; sl. s. al.].	Effective against cutaneous leishmaniasis; bactericide; has very bitter taste; stimulates heart rate; excreted in urine.
6	Caffeine $C_8H_{10}N_4O_2$ [B + Na benzoate]	Coffee (Coffea arabica), tea (Thea sinensis).	Tropical, subtropical areas.	MP = 238; opt. inactive.	s.w.1:46, al.1:66, chl.1:5.5; si.s.eth., pet, eth.; [s.w.1:1:1., al.1:30].	Causes mild CNS stimulation, particularly cortex and medullary centers. Relaxes vascular musculature, stimulates heart and skeletal muscle, causes diuresis. [Contains approx. 50% caffeine.]
7	Cevadine (Veratrine) $C_{32}H_{49}NO_9$	Hellebore (rhizome) (Veratrum spp).	Europe, U.S.	MP = 205; $(a)_D$ = +12.5° in al.	s. al., eth. 1:15; i.w.	Action like veratramine.
8	Cinchonidine $C_{19}H_{22}N_2O$ [B_2·H_2SO_4]	Cinchona spp.	S. America, Java.	MP = 210; $(a)_D$ = -109° in al.	s. al., chl.; mod. s. eth.; f.w.; [s.w.1:70].	Antimalarial, see quinine.
9	Cinchonine $C_{19}H_{22}N_2O$ [B_2·H_2SO_4·$2H_2O$]	Cinchona spp.		MP approx. 265; $(a)_D$ = +229° in al.; [MP approx. 198].	s. al.1:60, chl. 1:110; sl.s. eth.;i.w.; [s.w.1:65, al.1:12].	Antimalarial, see quinine.
10	Cocaine $C_{17}H_{21}NO_4$ [B·HCl]	Erythroxylum coca (leaf).	S. America, Java.	MP = 98; $(a)_D$ = -16° in chl.; [MP approx 195; $(a)_D$ = -72° in w.].	s. w. 1:600, al. 1:65; fats v.s. chl., eth.; [v.s.w., al.; s.eth., fats].	Local anesthetic, absorbed both from mucous membrane or by injection; CNS stimulation, particularly cortex; potentiates sympathetic nervous system, causes vasoconstriction; habit-forming, but does not cause true addiction.
11	Codeine $C_{18}H_{21}NO_3$·H_2O a[B_2·H_2SO_4·$5H_2O$] b[B·H_3PO_4·$1\frac{1}{2}$ H_2O]	Poppy, opium (Papaver somniferum), also from morphine.	Asia Minor, India.	MP = 155; $(a)_D$ = -136° in al.; $(a)_D$ = -112° in chl.; a[$(a)_D$ = -101°] in w.].	s.w.1:120, al.1:2, bz., chl.; i.pet., eth.; s[s.w.1:30, al. 1:1020]; b[s.w.1:2.3, in chl.; al.1:325].	Narcotic, analgesic, sedative, antitussive. Less potent than morphine. Causes true addiction.
12	Colchicine $C_{22}H_{25}NO_6$	Saffron (seed and corm) (Colchicum autumnale).	Europe, N.Africa.	MP = 157; $(a)_D$ = -121° in chl.; $(a)_D$ = -429° in w.	s. sl., chl., w.1:22, bz.1:100.	Causes transient fall in number of leucocytes; appears to stimulate karyokinesis in bone marrow; arrests cell division in metaphase; causes bizarre mitotic figures; relieves acute gout.
13	Conessine $C_{24}H_{40}N_2$	Conessi (bark). (Holarrhena antidysenterica).	India.	MP = 125; $(a)_D$ = -25 in al.	s. al., chl.; sl. s.w.	Local anesthetic; causes necrosis; kills Entamoeba histolytica (effective orally).
14	Coniine $C_8H_{17}N$ [B·HBr]	Poison hemlock (Conium maculatum)	Europe.	MP = -2; BP =166; $(a)_D$ = +16° (no solvent); [MP = 207].	s. al., eth., acet., bz., al.s.w.; [s.w., al., chl., eth.].	Paralyses motor nerve endings; first stimulates, then depresses CNS, [Has been used as sedative, antispasmodic.]
15	Emetine $C_{29}H_{40}N_2O_4$ [B·2HCl + 3 to $8H_2O$]	Ipecac (root) (Cephaelis ipecacuanha).	Brazil.	MP = 74; $(a)_D$ = -50° in chl.	s. al., eth., chl.; si.s.w., pet, eth.; [s.w. approx. 1:7].	Kills Entamoeba histolytica; toxic to heart, skeletal muscles; concentrated in liver.
16	Ephedrine $C_{10}H_{15}NO$·$\frac{1}{2}$ H_2O a[B·HCl] b[B_2·H_2SO_4]	Ephedra spp, also synthetic.	China, India.	MP approx. 40; $(a)_D$ = +1° in w.; a[MP approx. 216; $(a)_D$ = -34° in w.]; b[d.245; $(a)_D$ = -30° in w.].	s. al., eth., chl., oils, w.1:20; a[s.w.1:3, al. 1:14]; b[s.w.1:2, al.1:95].	Sympathomimetic; stimulates CNS and heart mucle; raises blood pressure; constricts arterioles; relaxes smooth muscle of bronchi and gastrointestinal tract; dilates pupil; increases metabolic rate; readily absorbed from intestinal tract.
17	Ergonovine $C_{19}H_{23}N_3O_2$ [B·$C_4H_4O_4$ (maleate)]	Ergot (Claviceps purpurea).	Russia, Finland, Spain, Portugal, U.S. (Minnesota)	MP = 162; $(a)_D$ = +44° in chl.; [d. 167; $(a)_D$ = +48° to +57° in w.].	s. al., acet., eth.ac.; mod. s.w.; [s.w.1:36, al.1:120].	Stimulates uterus, causing rapid contraction; absorbed from GI tract.
18	Ergotamine $C_{33}H_{35}N_5O_5$ [B_2·tartrate + $2CH_3OH$]	Ergot (C. purpurea).		d. 212-214; $(a)_D$ =-160° in chl.; [$(a)_D$ = -125° to -155° in chl.].	s.chl., pry, me.al. 1:70, acet,1:150; [s.w., al. 1:500]	B usually cryst. solvated, e.g., + 2 acet. + $2H_2O$. Stimulates uterus; causes peripheral vasoconstriction; causes adrenergic blockage; stimulates and depresses CNS; depresses heart; causes vomiting.
.19	β-Erythroidine $C_{16}H_{19}NO_3$	Coral tree (seed) (Erythrina americana).	N. America,	MP = 100; $(a)_D$ = +89° in w.	s.w., chl., al., bz.; mod. s. eth.	Blocks myoneural junction, causing skeletal muscle paralysis; CNS depressant; absorbed from GI tract.
20	Heroin (diamorphine) $(C_{21}H_{23}NO_5)$ [B·HCl·H_2O]	Morphine.		MP = 173; $(a)_D$ = -166° in me. al.; [MP = 244; $(a)_D$ = -156° in w.].	s.chl.1:1.5, al.1.31, eth.1:100;sl.s.w.; [s.w.1:2, al.1:1] i.pl.,eth.].	Narcotic, action similar to morphine, more potent but shorter duration. Causes euphoria and severe addiction; production illegal in most countries.
21	Hydrastine $C_{21}H_{21}O_6N$ [B·HCl]	Orange-root (root) (Hydrastis canadensis).	N. America.	MP = 132; $(a)_D$ = -50 in al.; [$(a)_D$ = +127 in chl. HCl].	s. chl., acet., bz.; sl.s.al., eth.; [s.w., al.].	Oxytocic; internal styptic in uterine hemorrhage; stimulates spinal center; excreted unchanged in urine.
22	Hyoscyamine $C_{17}H_{23}NO_3$ [B·HCl]	Solanaceae.	World-wide.	MP = 108.5; $(a)_D$ = -21° in al.; [MP = 149-151].	s. al., chl., bz.1:150, w.1:280; [s.w., al.].	The levo-rotatory constituent of atropine. Action like that of atropine.
23	Lobeline $C_{22}H_{27}NO_2$ [Lobelia inflata), [B·HCl]	Indian tobacco, (Lobelia inflata), also synthetic.	N. America.	MP = 130-131; $(a)_D$ = +43° in al.; [MP = 178-180].	s. chl., bz., hot al.; i.w.; pet.eth.; [s.w. 1:40, al. 1:12; v.s.chl.].	Action like that of nicotine, less potent.

24	Mescaline $C_{11}H_{17}NO_3$ [B·HCl]	Mescal cactus (flesh) (Anhalonium Lewinii).	Southwestern U.S., Mexico.	MP = 35-36; opt. inactive; [MP = 181].	s. al., chl., bz.; sl.s.w.; i.eth., pet. eth.; [s.w., al.].	Depresses CNS; produces psychic effects and visual color hallucinations.
25	Morphine $C_{17}H_{19}NO_3 \cdot H_2O$ Opium. see codeine. a [B·HCl·3H$_2$O] b [B$_2$·H$_2$SO$_4$ 5H$_2$O]			d. 254; $(\alpha)_D$ = -132° in me.al.; a [d. approx. 200; (a) = -111° in w.]; b [$(\alpha)_D$ = -95° in w.].	s.a.l.:210; chl.,l:2200, hot me.al.:110, alkalies; a [s.w.:1:7, al.1:50] ; b [s.w.:1:5, al.1:565].	Narcotic action in man; produces analgesia and sleep; depresses respiration; constricts pupils; relieves pain; contracts smooth muscles; effects constipation; retards secretion of HCl by stomach; little effect on blood pressure, heart rate or rhythm; readily absorbed from the GI tract; principally destroyed in body and excreted in urine. Causes true addiction.
26	Narcotine $C_{22}H_{23}NO_7$	Opium.		MP = 176; $(\alpha)_D$ = -207° in chl.	s.chl.:12, bz.:1:30, al.1:250; sl.s. hot w.	Action like that of papaverine, but less potent. Has antitussive properties.
27	Nicotine $C_{10}H_{14}N_2$ [B_2·H_2SO_4]	Tobacco (leaf, stem) (Nicotiana spp.).	World-wide.	BP = 247; $(\alpha)_D$ = -169° in w.; n_D = 1.5282; [$(\alpha)_D$ = +8.8° in w.].	s.w., eals, most organic solvents; [s.w., al.].	Causes initial and transient stimulation, then depression, paralysis of autonomic ganglia; mild CNS stimulation; paralyzes skeletal muscle; absorbed from skin and mucous membrane; rapidly detoxified. Insecticide.
28	Papaverine $C_{20}H_{21}NO_4$ [B·HCl]	Opium, also synthetic.		MP = 147; opt. inactive; [MP = 225].	s.al.:1:45, hot al.1:4; sl.s.eth., bz., pet.eth.; i.w.; [s.el., chl., w.:1:40].	No narcotic action; paralyses smooth muscle of intestines and blood vessels.
29	Pelletierine $C_8H_{15}NO$ [B· tannate]	Pomegranate (bark) (Punica granatum).	Subtropical lands.	BP = 195 (inert atmosphere); a s mixture; [tannic acid salt of several Punica alkaloids].		Easily oxidized, becoming resinous in air. Acts on central and and peripheral nervous system, voluntary muscle; selectively acts on optic nerve; effective against tapeworm.
30	Physostigmine (Eserine) $C_{15}H_{21}N_3O_2$ [B·$C_7H_6O_3$ (salicylate)]	Calabar bean (Physostigma venenosum).	W. Africa, India, Brazil.	MP = 105; $(\alpha)_D$ = -76° in chl., -120° in bz.; [MP = 185-187].	s.al., bz., chl., oils; s.w.:1:75, al. 1:16, chl. 1:6].	Inhibits cholinesterase, acts to stimulate skeletal muscle and as parasympathomimetic; causes pupillary constriction and spasm of accommodation; readily absorbed from GI tract and increases tone and motility; eliminated through kidneys.
31	Pilocarpine $C_{11}H_{16}N_2O_2$ [B·HNO$_3$]	Jaborandi (Pilocarpus spp).	S. America.	MP = 34; $(\alpha)_D$ = +100° in chl.; [MP = 178; $(\alpha)_D$ = +83° in w.].	s.w., al., chl.; i.eth.; [s.w.:1:6.4].	Parasympathomimetic; stimulates involuntary smooth muscle, gland cells, sweat, salivary and gastric glands; causes pupillary constriction; diaphoretic; depresses heart; partly destroyed in body; greater part excreted in urine.
32	Protoveratrine $C_{32}H_{51}O_{11}N$	Hellebore (root). (Veratrum viride)	N. America	MP = 283; $(\alpha)_D$ = -9 in chl.	s.al., chl.; i.w., bz.	Slows heart rate; lowers systemic blood pressure; side effects include nausea, diarrhea.
33	Quinidine $C_{20}H_{24}N_2O_2 \cdot 2H_2O$ [B_2·H$_2$SO$_4$·2H$_2$O] b [B·H$_2$SO$_4$·4H$_2$O]	Cinchona spp. also by isomerization of quinine.	S. America, Java.	MP = 175; $(\alpha)_D$ = +230° in chl.; a [$(\alpha)_D$ = +212° in al.].	s. al. 1:36, chl. 1:16, eth., 1:56; sl. s.w.; a [s.w.:1:90]; b [s.w.:1:8].	Stereoisomer of quinine. Acts on heart to increase excitability, slow conduction and increased refractory period; can stop auricular fibrillation; like quinine in other actions.
34	Quinine $C_{20}H_{24}N_2O_2$ (also + $3H_2O$) a [B_2·H$_2$SO$_4$·2H$_2$O] b [B.H$_2$SO$_4$ ·7H$_2$O] c [B·HCl·2H$_2$O]	Cinchona spp (bark).	S. America, Java.	MP = 177; $(\alpha)_D$ = -169° in al., -117° in chl.	s.al.1:1, chl. 1:1.2, bz.1:80, eth. 1:250; a [s.al.1:120, w.1:810]; b [s.w.1:9]; c [s.w.1:14].	Lethal to asexual erythrocyte forms of malarial parasite; mildly stimulates uterus; antipyretic; local irritant; absorbed from GI tract; largely destroyed in body. Cardiac actions like that of quinidine but less pronounced.
35	Reserpine (Serpasil) $C_{33}H_{40}N_2O_9$	Rauwolfia serpentina.	India.	MP = 278; $(\alpha)_D$ = -118° in chl.	s.chl., bz., eth.ac.; sl.s. acet., me.al., eth., w.	Hypotensive, CNS sedative action.
36	Scopolamine (Hyoscine) $C_{17}H_{21}NO_4$	Datura, Hyoscyamus, and Scopolia spp.	World-wide.	Liquid; $(\alpha)_D$ = -28° in w.; also cryst. + H_2O, MP = 54; [MP = 195 (anhydrous); $(\alpha)_D$ = -26° in w.].	s.al., eth., chl., w.: 1:95; sl. s.bz., pet.eth.; [s.w.:1:1.5, al.1:20] .	Causes sedation, sleep, and amnesia; otherwise like atropine.
37	Sparteine $C_{15}H_{26}N_2$ [B·H$_2$SO$_4$·5H$_2$O]	Lupinus and Spartium spp.	Europe.	Liquid; BP = 173 at 8 mm Hg; n_D at 1.5132; $(\alpha)_D$ = -16.4° in al.; [d. 1.36].	s.al., chl., eth., w.: 1:325; [s.w.:1:1, al.1:3].	Paralyzes autonomic ganglia; slows heart rate; curare-like action.
38	Strychnine $C_{21}H_{22}N_2O_2$ [$(B_2$·H$_2$SO$_4$·5H$_2$O, also 6H$_2$O]	Strychnos spp (seed), especially Strychnos nux-vomica.	India, Indo-China.	MP = 268-90, varies with rate of heating; $(\alpha)_D$ = -139° in chl.	s.chl.:1:5, al. 1:150, bz.:1:80; i.w.; [s.w.:1:35, al.:1:8], glyc.:1:6].	Stimulates CNS; increases reflex excitability of spinal cord; sensitizes sensory cortex, medulla; readily absorbed from GI tract.
39	Theobaine $C_{19}H_{21}NO_3$	Opium.		MP = 193; $(\alpha)_D$ = -219° in al.	s. hot al.1:15, chl, 1:13, bz.:1:25, pyr.:1:2, sl. s.w., al.; s. alkali.	Violent tetanic poison, no med. use per se. Source material for valuable narcotics.
40	Theobromine $C_7H_8N_4O_2$	Cacao bean (Theobroma cacao).	S. and Central America.	Sublimes 290; opt. inactive.	s.al.:1:200, hot al.1:80, chl. 1:110, alkali; s.w.:1:25].	Action like that of caffeine.
41	Theophylline $C_7H_8N_4O_2$ [B·Na acetate]	Tea (Thea sinensis), also synthetic.	China, India.	MP = 270-274; opt. inactive.	s.w.:1:120, al. 1:80, chl. 1:110, alkali; s.w.:1:25].	Action like that of caffeine. [Contains 27% N_a acetate.]
42	Tubocurarine chloride $C_{38}H_{44}N_2O_6Cl_2 \cdot 5H_2O$	Curare (Chondrodendron tomentosum).	S. America	d. 268; $(\alpha)_D$ = +1900° in w.	s.w.:1:20, al.1:cchl., bz., pyr., acet.	Paralyzes skeletal muscles by blocking myoneural junction; blocks autonomic ganglia; not absorbed from GI tract.
43	Veratramine $C_{27}H_{39}NO_2$	Veratrum spp.	N. and S. America.	MP = 206; $(\alpha)_D$ = -71° in al.	s. al., me.al.	Inhibits cardioacceleration of epinephrine, sympathomimetic amines; CNS stimulant.
44	Yohimbine $C_{21}H_{26}N_2O_3$ [B·HCl]	Corynanthe yohimbe.	Africa	MP = 234; $(\alpha)_D$ = +108° in pyr.; [MP = 302; $(\alpha)_D$ = +103° in w.].	s.al., chl.; sl.s.eth., w.; [s.w.:1:120, al. 1:400].	Adrenolytic; causes antidiuresis; mild local anesthetic.

/1/ In salt formula, B = base. /2/ Abbreviations: acet. = acetone; al. = alcohol (ethyl 95%); bz. = benzene; chl. = chloroform; d. = decomposes; dil. = dilute; eth. = ether; eth. ac. = ethyl acetate; glyc. = glycerol; i. = insoluble; me.al. = methyl alcohol; mod. = moderately; opt. = optically; pet. eth. = petroleum ether; pyr. = pyridine; s. = soluble; sl. = slightly; v. = very; w. = water. /3/ CNS = central nervous system; crys. = crystalline; GI = gastrointestinal; med. = medicinal.

Part I: IRRITANTS

	Plant	Type or Class	Compound	Irritant Empirical Formula	Toxic Action or Effect
1	Anemone (Anemone japonica)	Oil	Protoanemonin	$C_5H_4O_2$	Local irritation.
2	Baneberry (Actaea spp)				Acrid juice an emeto-purgative; cardiotoxic.
3	Chaulmoogra oil (Hydnocarpus spp)	Cylic acid	Chaulmoogric acid	$C_{18}H_{32}O_2$	Irritation of digestive tract, liver, kidneys.
4	Christmas rose (Helleborus niger)	Glycoside	Helleborein	$C_{37}H_{58}O_{18}$	Intense irritation of mucous membranes.
5	Conringia (Conringia orientalis)	Volatile oil	Allyl isothiocyanate	C_3H_5CNS	Local irritation.
6	Crab's-eye vine (Abrus precatorius)	Toxalbumin	Abrin		Severe gastroenteritis.
7	Croton (Croton tiglium)		Croton resin		Severe local irritation.
8	Cyclamen (Cyclamen europeaum)	Glycosidal saponin	Cyclamin		Irritation of gastrointestinal tract.
9	Daphne (Daphne mezereum)	Glycoside	Daphnin	$C_{15}H_{16}O_9$	Irritation of gastrointestinal tract; convulsions.
10	Indian turnip (Arisaema triphyllum)	Saponin			Irritation of mucous membranes; gastroenteritis.
11	Juniper (Juniperus spp)	Volatile oil			Inflammation of gastrointestinal tract.
12	Milkweed (Calotropis spp)	Milky juice			Violent local irritation; fatal gastroenteritis.
13	Mustard (Brassica spp)	Volatile oil	Allyl isothiocyanate	C_3H_5CNS	Local irritation.
14	Pine (Pinus spp)	Volatile oil	Oil of turpentine		Irritation of skin, kidneys.
15	Pyrethrum flowers (Chrysanthemum cinerariaefolium, C. coccineum, or C. marschallii)		Pyrethrin I	$C_{21}H_{30}O_3$	Irritation of eyes and mucous membranes.
16			Pyrethrin II	$C_{22}H_{32}O_5$	
17			Cinerin I	$C_{20}H_{28}O_3$	
18			Cinerin II	$C_{21}H_{28}O_5$	
19	Radish (Raphanus raphanistrum)	Volatile oil	Allyl isothiocyanate	C_3H_5CNS	Local irritation.
20	Skunk cabbage (Symplocarpus foetidus)				Severe irritation of mucous membranes; violent gastroenteritis may be fatal.
21	Snakeroot (Aristolochia spp)	Volatile oil	Borneol ester, pinene		
22		Alkaloid	Aristolochine	$C_{17}H_{19}NO_3$	Irritation of gastrointestinal tract, kidneys.
23	Sneezeweed (Helenium autumnale)		Helenalin		Gastroenteritis, muscular paralysis.
24	Sneezeweed (H. hoopesii)	Glycoside	Dugaldin		Salivation, vomiting, diarrhea.
25	Snowberry (Chiococca racemosa)	Glycoside	Caincin	$C_{40}H_{64}O_{18}$	Emeto-cathartic; severe gastroenteritis.
26	Soap-bark tree (Quillaja saponaria)	Sapogenin	Quillaic acid	$C_{30}H_{46}O_8$	Severe local irritation.
27	Wood-fern (Dryopteris spp)		Aspidot	$C_{12}H_{14}O_4$	
28			Filicinic acid	$C_8H_{10}O_3$	Irritation of gastrointestinal tract.

Part II: REPELLENTS

	Plant	Type or Class	Compound	Empirical Formula	Repellent Insects Repelled	Toxicity to Higher Animals[1]
1	Camphor tree (Cinnamomum camphora)	Ketone	Camphor	$C_{10}H_{16}O$	Mosquitoes	Increased sensibility; convulsions.
2	Cinnamon tree (Cinnamomum spp)	Volatile oil	Oil of cinnamon		Mosquitoes	Inflammation of gastrointestinal tract.
3	Citronella grass (Cymbogon nardus)	Oil	Citronella, geraniol		Mosquitoes	
4	Eucalyptus (Eucalyptus spp)	Oil	Eucalyptol	$C_{10}H_{18}O$		Inflammation of stomach; nausea; vomiting;
5			Pinene	$C_{10}H_{16}$	Cockroaches	dizziness; muscular weakness; fatal
6			Eudesmol	$C_{15}H_{26}O$		collapse.
7	Horse-radish (Radicula armoracia)	Glycoside	Sinigrin	$C_{10}H_{18}KNO_9S_2$	Cockroaches	Corrosive; inflammation, vesication of skin.
8	Juniper (Juniperus communis)	Oil	Camphene	$C_{10}H_{16}$		
9			a-Pinene	$C_{10}H_{16}$	Cockroaches	Local irritation; may injure kidneys.
10			Terpineol	$C_{10}H_{18}O$		
11			Cadinene	$C_{15}H_{24}$		
12	Sassafras (Sassafras albidum)	Oil	Camphor	$C_{10}H_{16}O$		
13			Safrol	$C_{10}H_{10}O_2$	Screw-worm flies	Paralysis of respiratory center; fatty degeneration of heart, liver, kidneys.
14			Eugenol	$C_{10}H_{12}O_2$		
15	Thyme (Thymus vulgaris)	Volatile oil	Cymene, pinene, thymol		Mosquitoes	Excitement.
16	Wormseed (Chenopodium ambroisioides anthelmiticum)	Volatile oil	Ascaridole	$C_{10}H_{16}O_2$	Mosquitoes	Temporary deafness; convulsions; gastric irritation; nephritis.
17			Cymene	$C_{10}H_{14}$		

[1] When ingested or applied locally in high concentrations.

Part III: MISCELLANEOUS

	Plant	Toxic Component Type or Class	Compound	Empirical Formula	Toxic Action or Effect
1	Anamirta (Anamirta cocculus)	Neutral principle	Picrotoxin	$C_{30}H_{34}O_{13}$	Convulsions; paralysis; death by asphyxia.
2	Andromeda (Andromeda spp)	Neutral principle	Andromedotoxin	$C_{31}H_{50}O_{10}$	Vomiting; paralysis of motor nerve endings; cardiotoxin.
3	Aster (Aster xylorrhiza)	Resinous			Impaired vision; depraved appetite; abdominal pain.
4	Beet (Beta vulgaris), leaf only	Inorganic	Oxalic acid, nitrates	$C_2H_2O_4$	Inability to stand; muscular tremors, tetany.
5	Buckwheat (Fagopyrum esculentum)	Photodynamic	Porphyrin		Photosensitization.
6	Carissa (Carissa ovata)	Glycoside	Carissin	$C_{32}H_{50}O_{12}$	Heart derangement.
7	Cocklebur (Xanthium spp)	Glycoside	Xanthoatrumarin		Depression; nausea, vomiting; labored respiration.
8	Coriaria (Coriaria myrtifolia)	Glycoside	Corismyrtin	$C_{15}H_{18}O_5$	Convulsions; paralysis; death by asphyxia.
9	Cotton (Goasypium hirsutum), seed only		Gossypol	$C_{30}H_{30}O_8$	Edema of lungs; irritation of kidneys, gastrointestinal tract.
10	Dogbane (Acokanthera venenata)	Glycoside	Abyssinin (ouabain)	$C_{32}H_{50}O_{12}$	Inflammation, gastrointestinal tract; cardiotoxin.
11	Flax (Linum usitatissimum)	Glycoside	Phaseolunatin	$C_{10}H_{17}O_6N$	Asphyxia.
12	Hyena poison (Hyaenanche capens)		Hyaenanchin	$C_{15}H_{18}O_7$	Convulsions; paralysis; death by asphyxia.
13	Laurel (Kalmia spp)		Andromedotoxin	$C_{31}H_{50}O_{10}$	See Andromeda, Line 2.
14	Lippia (Lippia rehmanni)	Photodynamic	Porphyrin		Photosensitization.
15	Marsdenia (Marsdenia cundurango)	Glycoside	Icterogenin	$C_{34}H_{52}O_6$	
16	Oleander (Nerium oleander)	Glycoside	Condurangin	$C_{35}H_{54}OOCH_3)_2$	Convulsions followed by paralysis.
17	Rhubarb (Rheum spp), leaf only	Glycoside	Oleandrin	$C_{31}H_{48}O_9$	Digitalis-like action.
18	Sorghum (Sorghum halepense)	Inorganic	Oxalic acid	$C_2H_2O_4$	Weakness; muscular tremors; tetany.
		Cyanogenetic glycoside	Dhurrin	$C_{14}H_{17}O_7N \cdot H_2O$	Asphyxia.
19	Strophanthus (Strophanthus spp)	Glycoside	Ouabain	$C_{29}H_{44}O_{12} \cdot 8H_2O$	Digitalis-like action.
20	Sweetclover (Melilotus spp), spoiled	Anticoagulant	Dicoumarin	$C_{19}H_{12}O_6$	Hemorrhages; retards blood coagulation.
21	Veronia (Veronia nigritiana)	Glycoside	Vernonin	$C_{10}H_{24}O_7$	Digitalis-like action.
22	Water hemlock (Cicuta spp)	Neutral principle	Cicutoxin	$C_{19}H_{26}O_3$	Violent convulsions.
23	Wild cherry (Prunus spp)	Cyanogenetic glycoside	Prunasin		Asphyxia.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part I: MAMMALS

	Mammal	Specification	Site	Temperature °C (°F)	Duration	Humidity %	Survival n/n'
1			R	25-29(77-84.2)	1 hr		0/7[5]
2	Man (Homo sapiens)	Adult	W	15(59)	50-70 min		6/6[3]
3			A	29-36(84.2-96.8)		36-84[4]	
4			A	43-48(109.4-118.4)		11-21[5]	
5	Anteater, spiny (Tachyglossus aculeatus)	2.36 kg	I[6]	26-29(78.8-84.2)[7]	77-102 min		3/3
6		1.67 kg	I[6]	40(104)[8]	70 min		0/1
7	Armadillo (Dasypus novemcinctus)	Adult	I[6]	29-33(84.2-91.4)[9]	3-6 hr		6/6
8	Bat (Myotis lucifugus)	5.2 g	A	0.5(32.9)[10]	2 hr		5/5
9		6.4 g	A	44(111.2)[11]	30 min		0/5
10	Cat (Felis catus)	Adult	I[6]	43(109.4)[12]	Few min	Dry air	50%
11			A	41-43(105.8-109.4)[13]	7 hr	35-65[13]	100%
12	Cattle (Bos indicus, B. taurus)	Adult	A	-13(8.6)[14]	2 wk	66	6/6
13		195-300 kg	A	41(105.8)[14]	24 hr	51	3/3
14	Dog (Canis familiaris)	Adult	I[6]	17(62.6)[15]	65-118 min		0/6
15		Adult	I[6]	22-26(71.6-78.8)[16]	15 min-26 hr		3/11
16		Adult	I[6]	42(107.6)[12]	Few min	Dry air	50%
17		27.6 kg	W	0(32)[17]	1-5 hr		4/4
18	Guinea pig (Cavia porcellus)	Adult	I[6]	41-42(105.8-107.6)[18]	7 hr		2/2
19			A	48(118.4)	100 a 4 min	15	0/11
20	Hamster, golden (Mesocricetus auratus)	Adult	I[6]	2-4(35.6-39.2)[19]			8/20
21			A	4-6(39.2-42.8)	6 da		22/45
22	Mouse (Mus musculus)	45-109 g	I[6]	9-15(48.2-59)[20]	25-65 min		20/20
23		Adult	A	38(100.4)[12]	3 hr		50%
24	Rabbit (Oryctolagus cuniculus)	Adult	I[6]	19-25(66.2-77)[21]	30 min		87/103
25		1.76 kg	A	-35(-31)[22]	3½-6½ hr		0/9
26		Adult	W	3.5 av (38.3)[23]	21 min (ev)		16/24
27		3.95 kg	W	10(50)[24]	30 min		4/4
28		Adult	A	35(95)[25]	7 hr	95[25]	2/2
29		Adult	A	38(100.4)[25]	7 hr	35[25]	2/2
30	Rat (Rattus rattus)	235 g	A	-35(-31)[22]	45-120 min		0/12
31		237 g	W	10(50)[24]	10 min		3/3
32		Adult	A	40(104)[26]	213 a 36 min	15	0/16
33		Adult	A	49-51(120.2-123.8)[26]	31 a 1 min		0/36
34	Sheep (Ovis aries)	Adult	I[6]	42(107.6)[12]	7 hr		100%
35			A	43(109.4)[27, 28]	7 hr	65	100%
36	Sloth (Bradypus griseus and/or Choloepus hoffmani)	Adult	I[6]	24(75.2)[29]			1/2
37			I[6]	40 ± (104±)[30]			
38	Squirrel (Citellus pygmaeus)	120-265 g	B	2-6(35.6-42.8)[31]			11/19
39	Swine, Berkshire (Sus scrofa)	59 kg	I	42(107.6)[17]			100%
40			A	38-41(100.4-105.8)[32]			

/1/ n = number survived; n' = number in test. Percentages are per cent survived. /2/ WW II concentration camp; subjects cooled rapidly in water. /3/ Subjects refused to continue, or investigator considered continuance detrimental. /4/ Range at onset of heat exhaustion in humid climates. /5/ Range at onset of heat exhaustion in desert climates. /6/ May include rectum and colon. /7/ In metabolic chamber placed in water bath at 4-8°C (39.2-46.4°F). /8/ In metabolic chamber placed in water bath at 35-37°C (95-98.6°F). /9/ In cold room at 0-21°C (32-69.8°F). /10/ In metabolic chamber; -5°C (23°F) fatal to hibernating bats. /11/ In metabolic chamber at high humidity. /12/ Temperature for 50% mortality estimated from curve. /13/ Upper limits of temperature and humidity cats can withstand for 7 hr. /14/ Indoors; air flow 22.9 cm/sec. /15/ In ice water at 1.5-6°C (34.7-42.8°F); dogs etherized during initial cooling stages. /16/ Anesthetized and cooled with ice for 1 1/4 to 27 hr. /17/ Serious impairment in 3 dogs in 1 hr; 4th not markedly affected. /18/ 7 hr exposure to environmental temperature of 41°C (105.8°F). /19/ In cold water at 3°C (37.4°F), or in cold air. /20/ In cold air, about -10°C (14°F). /21/ Immersed in cold water, then exposed to cold air (total ½ hr). /22/ In controlled temperature room, air flow 89.4 cm/sec. /23/ Body temperature in all but three fell below 19°C (66.2°F). /24/ Serious impairment, approaching unconsciousness. /25/ Upper limits tolerated for 7 hr in controlled temperature room. /26/ In heated room. /27/ In controlled temperature room; near heat tolerance limit. /28/ Merino wethers sheep. /29/ In cold room, 10-16°C (50-60.8°F); rectal temperature of 23-25°C (73.4-77°F) for 7 hr for animal that died and for 9 hr for survivor. /30/ Outdoor exposure at 35-40°C (95-104°F) in sunlight; several died. /31/ In refrigerator 2-4 hr at -13 to -19°C (8.6 to -2.2°F); all but one of eight that died had body temperature of 0°C (32°F) or less. /32/ In controlled temperature room; withstood 38°C (100.4°F) at 65 relative humidity, but could not tolerate 41°C (105.8°F) at any humidity.

Part II: BIRDS

	Bird	Specification	Body Temperature Site	°C (°F)	Ambient Temperature Site	°C (°F)	Duration hr	Survival n/n'
1	Canary (Serinus serinus canaria)	20 g			A	-35 (-31)	0.6	0/2
2	Duck (Anas platyrhynchos)	1.45-1.8 kg			A	-40 (-40)	168-264	0/3
3	var. domesticus	2 kg			A	-40 (-40)	384	1/1
4	wild mallard	1 kg			A	-18 (-0.4)	225	0/8
5		♂	C	19.4-22.2 (68.9-72)	W	6-10 (42.8-50)	1.1-1.5	6/6
6		♀	C	22.8-23.6(73-74.5)	W	9-11.7(48.2-53.1)	1.1-1.5	0/5
7		♀	C	27.8-29.4(68-84.9)	W	20-27.8(68-82)	35-44	0/5
8		♀	C	27.8-31.1(68-88)	W	20-27.8(68-82)	23-37	5/5
9		1.6 kg	C	21-41(69.8-105.8)	A	-35(-31)	3.3-16	0/8
10	Fowl (Gallus gallus) var. domesticus	1.5 kg	C	21-41(69.8-105.8)	A	-35(-31)	16-29.5	0/3
11		Embryo (0 da)			A	-5(23)	48	50%
12		Embryo (5 da)			A	0(32)	38	49%
13		Embryo (17 da)			A	10(50)	144	60%
14		Embryo (0-5 da)			A	21(69.8)	120	50%
15		Embryo (0-21 da			A	28(82.4)	504	50%
16		Embryo (0-21 da)			A	43(109.4)	504	50%
17		21.8 g			A	-14(6.8)	37	0/12
18	Junco, slate-colored (Junco hyemalis)	20.7 g			A	37(98.6)	12	0/3
19		1.05 kg			A	-9 (15.8)	336	0/16
20	Pheasant, ring-neck (Phasianus colchicus)	1.15 kg			A	-1 a (30.2a)	340	0/24
21			R	46(114.8)			<1	50%
22	Pigeon (Columba livia)	300-400 g			A	-40(-40)	0.3-0.5	0/7[2]
23		300-400 g			A^3	-40(-40)	24	4/6

/1/ n = number survived; n' = number in test. Percentages are per cent survived. /2/ Plucked birds. /3/ In path of 5 mph breeze.

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part II: BIRDS (Concluded)

	Bird	Specification	Body Temperature		Ambient Temperature		Duration	Survival n/n' [2]
			Site	°C (°F)	Site	°C (°F)	hr	
24	Pigeon (Columba livia) (concluded)	300-400 g			A^3	-40(-40)	48	0/6
25		300-400 g			A	40(-40)	96-120	1)/25
26		300-400 g			A	-40(-40)	144	4/25
27	Quail, bob white (Colinus virginianus)	165 g			A	-18 (0.4)	60	0/10
28	Grouse, ruffed (Bonasa umbellus)	615 g			A	-18(-0.4)	185	0/2
29		29 + g			A	-39 to -30(-38.2 to -22)	3.7-5.3	0/10
30					A	-29 to -20(-20.2 to -4)	3.2-4.4	0/8
31	Sparrow, house (Passer domesticus)				A	-19 to -10(-2.2 to 14)	11.3-21.4	0/37
32					A	38-39(100.4-102.2)	9.9-13.6	9/10
33					A	41-45(105.8-113)	0.5-1	0/7
35	Sparrow, tree (Spizella arborea)	21.1 g			A	-13(9.6)	31	0/3
36	Sparrow, white-crowned (Zonotrichia leucophrys)	20.5 g			A	38(100.4)	7	0/4
37		37.5 g			A	-18(0.4)	19	0/4
38	Sparrow, white-throated (Zonotrichia albicollis)	32.4 g			A	38(100.4)	5	0/3
39		26.6 g			A	-17(1.4)	16	0/3
40	Turkey, wild (Meleagris gallopao)	27.8 g			A	-37(98.6)	7	0/20
41		4.9 kg			A	-18(0.4)	324	0/2
42					A	-13.9(7)	4	1/1
43	Wren, house (Troglodytes aedon)		T	6.8-11.3(44.2-52.3)	A	6.4-10.1(43.5-50.2)	<1	5/9
44			T	21.7(71.1)	A^4	10 ± (50±)	<1	0/1
45			T	23.7(74.7)	A^4	10 ± (50±)	<1	1/1
46			T	45.3(113.5)	A^5	37.9±(100.2)	<1	2/2
47			T	46.6(115.9)	A	45.2(113.2)	<1.5	1/11
47			T	46.8(116.2)	A^5	37.9 ± (100.2)	<1	0/4

/1/ n = number survived; n' = number in test. Percentages are per cent survived. /3/ In path of 5 mph breeze. /4/ Low and falling air temps.
/5/ High and rising air temps.

Part III: REPTILES

Values are LD_{50} temperature tolerance limits, i.e., temperatures survived by 50% of test animals. Counts were made after animals regained "normal" temperature and behavior. Information on site of measurement, if available, is given in brackets.

	Reptile	Lower Limit °C (°F)	Upper Limit °C (°F)
1	Alligator (Alligator mississippiensis)	4(39.2)[C]	39(102.2)[C]
2	Lizard, chuckwalla (Sauromalus obesus)		44(111.2)[C]
3	Lizard, collared (Crotaphytus collaris)		46(114.8)[C]
4	Lizard, crested (Dipsosaurus dorsalis)		47.5(117.5)[C]
5	Lizard, European (Lacerta agilis)	-4(24.8)	44(111.2)[B]
6	Lizard, fringe-footed (Uma notata)		45(113)[C]
7	Lizard, ground (Uta stansburiana)		48(118.4)[C]
8	Lizard, horned (Phrynosoma platyrhinos)		46(114.8)[C]
9	Lizard, night (Xantusia vigilis)		38(100.4)[C]
10	Lizard, slowworm (Anguis fragilis)		37(98.6)[A]
11	Lizard, swift (Sceleroporus graciosus)		43.6(110.5)[C]
12	Lizard, whiptail (Cnemidophorus tesselatus)		46(114.8)[C]
13	Snake, garter (Thannophis radix)	-2(28.4)[U]	
14	Snake, garter (T. radix)	0(32)[A]	
15	Snake, glossy (Arizona elegans)		42(107.6)[C]
16	Snake, leaf-nosed (Phyllorhynchus decurtatus)		38(100.4)[C]
17	Snake, shovelnose (Sonora occipitalis)		37(98.6)[C]
18	Snake, sidewinder (Crotalus cerastes)		41(105.8)[C]
19	Snake, water (Natrix sipedon)	0(32)[A]	43(109.4)[A]
20	Turtle, central painted (Chrysemys belli marginata)		40(104)[C]
21	Turtle, land (Testudo horsefieldi)	-1(30.2)[B]	
22	Turtle, painted (Pseudemys elegans)	1(33.8)[C]	46(114.8)[C]
23	Turtle, snapping (Chelydra serpentina)	<4(<39.2)[C]	40(104)[C]

Part IV: AMPHIBIANS

Values are LD_{50} temperature tolerance limits, i.e., temperatures survived by 50% of test animals. Counts were made after animals regained "normal" temperature and behavior. Information on site of measurement, if available, is given in brackets.

	Amphibian	Lower Limit °C (°F)	Upper Limit °C (°F)
1	Bullfrog (Rana catesbeiana), embryo	15(59)[W]	32(89.6)[W]
2	Bullfrog (R. catesbeiana), large tadpoles[1]		36(96.8)[W]
3	Frog, green (R. clamitans)	-0.5(31.1)[S]	22(71.6)[A] [2]
4	Frog, green (R. clamitans), embryo	12(53.6)[W]	
5	Frog, leopard (R. pipiens), embryo[3]	11(51.8)[W]	34(93.2)[W]
6	Frog, leopard (R. pipiens), embryo[4]	5(41)[W]	28(82.4)[W]
7	Frog, pickerel (R. palustris), embryo	7(44.6)[W]	30(86)[W]
8	Frog, spring peeper (Hyla crucifer), embryo	<6(<42.8)[W]	28(82.4)[W]
9	Frog, tree (H. arbores)	-0.5(31.1)[C]	
10	Frog, water (Rana esculenta)	-0.5(31.1)[C]	
11	Frog, wood (R. sylvatica), embryo	2.5(36.5)[W]	24(75.2)[W]
12	Frog, European wood (R. temporaria), embryo	-1.4(29.5)[G]	32.5(90.5)[W] [5]
13	Salamander, European spotted (Salamandra maculosa)	-3(26.6)[W]	
14	Toad, American (Bufo americanus), embryo	11(51.8)[W]	31(87.8)[W]
15	Toad, clawed (Xenopus laevis)	0(32)[C]	33(91.4)[C]
16	Toad, common (Bufo bufo)	-1(30.2)[W]	33(91.4)[W] [5]
17	Toad, fire-bellied (Bombinator igneus)	-0.5(31.1)[C]	

/1/ Tadpoles of known ages, for brief exposures. /2/ 12 hr exposure. /3/ From Florida. /4/ From Vermont. /5/ 1 hr exposure.

Part V: FISHES

Values are LD_{50} temperature tolerance limits, i.e., water temperatures survived by 50% of test animals. Counts were made by observing or estimating the number killed during exposure, or within a reasonable time thereafter in which it could be safely assumed that all deaths were attributable to the temperature effects. Exposure periods, in hours, are given in brackets.

	Fish	Acclimated to °C (°F)	Lower Limit °C (°F) [hr]	Upper Limit °C (°F) [hr]
1	Bass, large mouth (Micropterus salmoides floridanus)	20(68)	5(41)[24]	32(89.6)[72]
2	Bluegill (Lepomis macrochirus macrochirus)[1]	30(86)	11(51.8)[24]	34(93.2)[72]
3		10(50)		28(82.4)[24]
4		30(86)		36(96.8)[24]
5	Bluegill (L. macrochirus	15(59)	3(37.4)[24]	31(87.8)[>60]
6	purpurescens)[1]	30(86)	13(51.8)[24]	34(93.2)[>60]
7	Bullhead (Ameiurus n. nebulosus, A. n. marmoratus)[1]	20(68)	1(33.8)[24]	32(89.6)[96]
8		30(86)	7(44.6)[24]	35(95)[96]
9	Catfish, channel (Ictalurus	15(59)	0(32)[24]	30(86)[>24]
10	lacustris lacustris, I. l. punctatus)[1]	25(77)	6(42.8)[24]	34(93.2)[>24]
11	Chub, creek (Semotilus a. atromaculatus)[1]		5(41)	25(77)[>96]
12			25(77)	32(89.6)[>96]
13	Dace, blacknose (Rhinichthys a. atratulus, R. a. meleagris)[1]		5(41)	25(77)
14				29(84.2)[24]
15	Eelpout (Zoarces angullaris)[3]		-2(28.4)[12]	28(82.4)[4]
16	Flounder, winter (Pseudopleuronectes americanus)[3]	-2(28.4)	1(6(60.8)	29(84.2)[2]
17	Goldfish (Carassius auratus)[1]		2(35.6)	28(82.4)[14]
18			17(62.6)	<0(32)[14]
19			24(75.2)	34(93.2)[14]
20			37(98.6)	36(96.8)[14]
21	Greenfish (Girella nigricans)[3]		12(53.6)	42(107.6)[14]
22			18(64.4)	43(109.4)[72]
23	Killifish (Fundulus heteroclitus)[3]		14(57.2)	31(87.8)[120]
24			20(68)	32(89.6)
25			[2(35.6)[48]	34(93.2)

/1/ Fresh-water fish. /2/ Upper limit in gradually rising temperatures. /3/ Marine fish. /4/ Approximate average survival time.

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part V: FISHES (Concluded)

Values are LD_{50} temperature tolerance limits, i.e., water temperatures survived by 50% of test animals. Counts were made by observing or estimating the number killed during exposure, or within a reasonable time thereafter in which it could be safely assumed that all deaths were attributable to the temperature effects. Exposure periods, in hours, are given in brackets.

	Fish	Acclimated to °C (°F)	Lower Limit °C (°F) [hr]	Upper Limit °C (°F) [hr]
25	Minnow, fathead	20(68)	2(35.6)[24]	32(89.6)[133]
26	(Pimephales promelas)[3]	30(86)	11(51.8)[24]	33(91.4)[133]
27	Minnow, blunt-nose	15(59)	1(33.8)[24]	31(87.8)[133]
28	(Hybognychus notatus)[1]	25(77)	8(46.4)[24]	33(91.4)[133]
29	Mosquito fish (Gambusia affinis affinis, G.a.holbrooki)	15(59) 35(95)	2(35.6)[24] 15(59)[24]	35(95)[>66] 37(98.6)[>66]
30	Perch (Perca flavescens)[1]	5(41)	2(35.6)[24]	21(69.8)[96]
31	Winter	25(77)	4(39.2)[24]	30(86)[>96]
32	Summer	25(77)	9(48.2)[24]	32(89.6)[>96]
33	Salmon, spring (Oncorhynchus tschawytscha)	5(41) 20(68)	4.5(40.1)[92]	21.5(70.7)[168] 25.1(77.2)[168]
34	Salmon, sockeye	5(41)	0(32)[92]	22.2(72)[168]
35	(O. nerka)	20(68)	6.7(40.9)[92]	24.8(76.6)[168]
36	Salmon, chum	5(41)		21.8(71.2)[168]
37	(O. keta)	20(68)	6.5(43.7)[92]	23.7(74.7)[168]
38	Salmon, coho	5(41)	0.2(32.4)[92]	22.9(73.2)[168]
41	(O. kisutch)	20(68)	4.5(40.1)[92]	25(77)[168]
42	Shad, gizzard (Dorosoma cepedianum)[1]	25(77) 35(95)	11(51.8)[24] 20(68)[24]	34(93.2)[48] 37(98.6)[48]

/1/ Fresh water fish. /3/ Marine fish. /5/ Summer. /6/ Winter.

	Fish	Acclimated to °C (°F)	Lower Limit °C (°F) [hr]	Upper Limit °C (°F) [hr]
44	Shiner, common	5(41)		27(80.6)[133]
45	(Notropis cornutus frontalis)[1]	25(77) 30(86)	4(39.2)[24] 8(46.4)[24]	31(87.8)[133] 31(87.8)[133]
47	Shiner, common (N. cornutus chrysocephalus)[1]	25(77)[5] 30(86)[6]		32(89.6)[133][5] 34(93.2)[133][6]
49	Shiner, lake	5(41)		23(73.4)[133]
50	(N. atherinoides)[1]	15(59) 25(77)	2(35.6)[24] 8(46.4)[24]	29(84.2)[133] 31(87.8)[133]
51	Shiner, golden	20(68)	8(46.4)[24]	32(89.6)[>66]
53	(Notemigonus c. crysoleucas, N. c. auratus)[1]	30(86)	11(51.8)[24]	35(95)[>66]
54	Sucker, common (Catostomus commersonni)[1]	15(59) 25(77)	5(41)[24]	29(84.2)[133] 29(84.2)[133]
56	Sunfish	10(50)		28(82.4)[24]
57	(Lepomis gibbosus)[1]	30(86)		24(75.2)[24]
58	Trout, brook	3(37.4)		23(73.4)[133]
59	(Salvelinus fontinalis)[1]	20(68)		25(77)[133]
60		25(77)		25(77)[133]

Part VI: INSECTS

Exposure periods, in hours, are given in brackets.

	Insect	Specifications	Activity Range °C (°F)	Biological Zero[1] °C (°F)	Heat Death °C (°F) [hr]	Heat Death R.H. %[2]	Cold Death Temperature °C (°F) [hr]
				Anoplura			
1	Louse, human (Pediculus	Adult	20-39(68-102.2)[3]		50-55(122-131)[0.25-0.42]		
2	humanus)	Adult			46-47(114.8-116.6)[1]	0-90	
3		Adult			33-38(91.4-100.4)[24]	0-90	
				Coleoptera			
4	Beetle, diving	Egg	10-27(50-80.6)	0(32)	31(87.8)		
5	(Dytiscus marginalis)	Larva		1.38(34.5)[4]			
6	Beetle, furniture (Anobium striatum)	Adult			42-46(107.6-114.8) [0.01-0.02]		
7	Beetle, Mexican bean (Epilachna varivestis)	Larva, adult			42.5(108.5)[1]	1-100	
8	Beetle, western pine (Dendroctonus brevicomis)	Larva	12.8-32(55-89.6)	4-7(39.2-44.6)[5]	37.8-40.6(100-105.1)[0.5]		5-10(41-50)
9	Mealworm, yellow (Tenebrio molitor)	Larva	12-20(53.6-68)[6]		42-43(107.6-109.4)[1-3]	0-90	
10		Larva			38.5(101.3)[24]	0-90	
	Tree borer, flat-headed apple-						
11	(Chrysobothris femorata)	Larva			53(127.4)[2]	10-15;95-100	
12	Weevil, bean (Acanthoscelides	Egg			52(125.6)[0.17]		-8(17.6)
13	obtectus)	Larva		-2(28.4)	55(131)[0.35]		-8(17.6)
14		Pupa		-2(28.4)	55(131)[0.42]		-9(15.8)
15		Adult		-2(28.4)	55(131)[0.06]		-8(17.6)
16	Weevil, boll (Anthonomus grandis)	Adult	13.3-35(55.9-95)	3to-4(37.4-24.8)[7]	50-60(122-140)		
17	Weevil, granary (Sitophilus granarius)	Adult	25(77)[6]	9.5(49.1)[9,10]	49(120.2)[3]	20-60	-4 to -1(24.8-30.2) [1104]
				Diptera			
18	Cheese skipper (Piophila casei)	Larva			46-48(114.8-118.4)[11][24]	0-100	
19	Fly, green bottle (Phaenicia	Egg	10-30(50-86)	5-6(41-42.8)			
20	sericata)	Larva	10-30(50-86)	4.2-10(39.6-50)[12]			
21		Adult	20-38(68-100.4)	6.7-7.2(44.1-45)[5]			
22	Fly, house (Musca domestica)	Egg			42.8-43(109-109.4)		
23		Larva	44-48(111.2-118.4)[13]	5(41)	49(120.2)		
24		Pupa	>7.8(>46)	10(50)			0-1(32-33.8)[168]
25		Adult	>15.6(>60.1)[6]	6.7-7.2(44.1-45)[5]	44.6(112.3)		0(32)[72]
26	Fly, tsetse (Glossina morsitans)	Adult			44-46(111.2-114.8)[0.08]		-12(10.4)[0.2]
27	Mosquito, malarial (Anopheles quadrimaculatus)	Larva			42(107.6)[0.12-0.3]		
28		Adult			42(107.6)[0.08]		
29	Mosquito, northern house (Culex pipiens)	Egg					5
30		Adult			44.5-45.6(112.1-114.1)		-17(1.4)
				Hemiptera			
31	Aphid, potato (Macrosiphum						
32	solanifolii)	Adult			38.5(101.3)[1]	60	
33	Bedbug (Cimex lectularis)	Adult	12-22(53.6-71.6)[14]	7.5(45.5)[5]			
					34-43.5(93.2-110.3)[15] [1-24]	0-90	
34	Greenbug (Toxoptera graminum)	Adult		1.7-4.5(35.1-40.1)[16]	37.5-40(99.5-104.2)		-8.3(46.9)
				Heteroptera			
35	Bug, assassin (Rhodnius prolixus)	Nymph			40-43([104-109.4][15] [1-24]	0-90	

/1/ Temperature at which all vital processes are arrested by cold. /2/ R.H. = relative humidity. /3/ Temp "preferred" by insect is 24-32°C (75.2-89.6°F). /4/ Cold stupor at 6°C (42.8°F). /5/ Cold stupor. /6/ Temp "preferred" by organism. /7/ Cold stupor at 13.3°C (55.9°F). /8/ Heat stupor at 35-50°C (95-122°F). /9/ Cold stupor at 13-15°C (55.4-59°F). /10/ Heat stupor at 28°C (82.4°F). /11/ The higher temp corresponds to a relative humidity of 60%. /12/ Cold stupor at 2°C (35.6°F). /13/ Temp "preferred" by larva is 30-37°C (86-98.6°F). /14/ Temp "preferred" by adult; relative humidity 24-44%. /15/ The higher temperature kills in 1 hr, the lower in 24 hr.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS (Concluded)

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part VI: INSECTS (Concluded)

Exposure periods, in hours, are given in brackets.

	Insect	Specifications	Activity Range °C (°F)	Biological Zero[1] °C (°F)	Heat Death °C (°F) [hr]	Heat Death R.H. %	Cold Death Temperature °C (°F) [hr]
	Hymenoptera						
36	Bee, honey (Apis mellifera)	Adult	20-35(50-95)		46-48(114.8-118.4)[0.5]		-2 to -1(28.4-30.2)
	Lepidoptera						
37	Borer, European corn-						
37	(Pyrausta nubilalis)	Larva					
38	Moth, codling	Egg			38(136.4)[0.18]		-31.7(-25.1)[0.17]
39	(Carpocapsa pomonella)	Larva		6.7-9.6(44.1-48.9) 6.1-8.8(43-47.8)			
	Orthoptera						
40	Cockroach, American (Periplaneta				42-45(107.6-113)[1]	0-90	
41	americana)	Adult			37-49(98.6-120.2)[24]	0-90	
42	Cockroach, German (Blattella						
42	germanica)	Adult			43-45(109.4-113)[1]	0-90	
	Siphonaptera						
43	Flea, oriental rat (Xenopsylla	Larva			40(104)[1]	0-90	
44	cheopis)	Adult			38-40.7(100.4-105.3)[15 [1-24]	0-90	

[1] Temperature at which all vital processes are arrested by cold. [2] R.H. = relative humidity. [15] The higher temperature kills in 1 hr, the lower in 24 hr.

363. OPTIMAL TEMPERATURES AND HUMIDITIES FOR PHYSIOLOGICAL FUNCTIONS: ARTHROPODS

Several ranges represent extremes reported by different investigators.

	Arthropod	Temperature °C	Optimal Humidity %	Function
	Isopoda			
1	Armadillium vulgare, adult	14-35	100	Survival
2	Ligia occidentalis, adult	20-35	100	Survival
3	L. pallasii, adult	20-35	100	Survival
4	Ligidium gracili, adult	20-35	100	Survival
5	Oniscus asellus, adult	14-18	100	Survival
6	Porcellio laevis, adult	20-35	100	Survival
7	Porcellionides pruinosus, adult	20-35	100	Survival
8	P. scaber, adult	14-35	100	Survival
9	P. spinicornis occidentalis, adult	20-35	100	Survival
	Acarina			
10	Haloty dieus destructor, adult	18-26	100	Survival
11	Ixodes ricinus, nymph	25-30	90-100	Development
12	I. ricinus, adult	25	100	Oviposition
	Anoplura			
13	Louse, horse-sucking (Hematopinus asini), egg	37.8	100	Survival
	Coleoptera			
14	Acilius sulcatus, adult	19	100	Survival
15	Beetle, capricorn (Hylotrupes bajulus), egg	16.6	50-60	Development
16		31.5	90-100	Survival, development
17	Beetle, caraboides (Hydrous carabioides), adult	18-20	100	Survival
18	Beetle, cigarette (Lasioderma serricorne), egg	32	75	Development
19	Beetle, clavicorn (Hydrophilus piceus), adult	18-20	100	Survival
20	Beetle, confused flour (Tribolium confusum), egg	27	1-75	Survival
21	pupa	27	0-25	Survival
22	Beetle, ladybird (Epilachna	27	76-81	Survival
23	corrupta), egg	27	81-100	Development
24	Beetle, oriental (Anomala orientalis), egg	25.5	100	Survival
25	Beetle, spider (Ptinus tectus), egg	25	70	Development
26	larva	24.7	70	Development
27	pupa	27	90	Development
28	Borer, grain (Rhyzopertha dominica), egg	18.3-38.2	90	Survival
29	Colymbetes fuscus, adult	15-20	100	Survival
30	Eurosta hilleri, egg	20	90	Development
31	Geotrupes stercorosus, adult	15-19	100	Survival
32	Lasmophloeus minutes, adult	21-25	90	Survival
33		21-25	55-90	Oviposition
34	Melasoma populi, egg	17-21	100	Development
35	adult	19-25	100	Survival
36	Weevil (Acanthoscelides obtectus) adult	26.6	100	Oviposition
37	egg	25.2	50-90	Development
38	Weevil, cowpea (Callosobruchus chinensis), larva	30.4	76	Survival, development
39	Weevil, cowpea (C. maculatus), egg	30	63	Survival, development
40	Weevil, granary (Sitophilus granarium), adult	20-27.5	60-100	Oviposition
41	Weevil, rice (Calandra oryza), egg	15-32	90	Survival
42	Wireworm (Agriotes lineatus), egg	19	100	Survival
43	larva	20	98-100	Survival
44	Dicyrtomia minuta, adult	25	100	Survival
45	Entomobrya multifasciata, adult	25	100	Survival
46	Isotoma viridis, adult	25	100	Survival
47	Sminthurus viridis, nymph	30	100	Survival
48	adult	7	80-90	Oviposition
49		25	100	Survival
50	Tomocerus vulgaris, adult	25	100	Survival
	Diptera			
51	Fly, green-bottle (Phaenicia sericata), egg	22	100	Development
52		37	90-100	Survival
53	Fly, heel (Hypoderma lineatum) pupa	20-25	0-76	Survival, development
54	Fly, tachinid (Winthemia quadripustulata), pupa	27	73.4	Development
55	Fly, vinegar (Drosophila melanogaster), pupa	18-19	100	Development
	Heteroptera			
56	Bedbug (Cimex lectularius), egg	13-35	75-90	Survival
57	nymph	18	44-77	Development
58	Bedbug (C. rotundis), egg	18	93	Survival
59	nymph	18	77-93	Development
60	Cone nose bug (Rhodnius prolixus), egg	17-33	70-90	Survival
61	Cotton stainer (Dysdercus cingulatus), egg	35	82-100	Survival
62	Eurygaster mauro, nymph	24-30	80-100	Survival
63	Palomena prasina, nymph	24-30	80-100	Survival
	Hymenoptera			
64	Wasp, parasitic (Habrobracon juglandis), egg	16-35	80	Survival
65	Wasp, parasitic (Macrocentrus ancylivorus), adult	26.7	80	Oviposition
	Lepidoptera			
66	Araschnia levana, pupa	18-20	55-85	Survival
67		18-20	100	Development
68	Armyworm (Prodenia littoralis), egg	29	90-95	Survival
69	Cutworm, grain (Agrotis segetum) pupa	17-21	65-85	Development
70	Dendrolimus pini, egg	24	80-85	Survival
71	Hoffmannophila pseudospretella, egg	15-25	90	Development
72		13-27	8.5-90	Survival
73	Hornworm, tomato (Protopraca quinquemaculata), pupa	27	0-73.4	Development
74	Moth, cecropia (Hyalophora cecropia), egg	25-21	56-76	Survival
75	Moth, lackey (Malacosoma neustria), egg	11-21	90	Survival
76	Moth, promethea (Callosamia promethea), egg	20-30	76	Survival
77	Moth, webbing (Tineola bisselliella), larva	23.9	75	Development
78	Panolis flammea, egg	12-22	65-85	Survival
79	Samia walkeri, egg	15-25	56-100	Survival
80	Silkworm (Bombyx mori), pre-pupa + pupa	25	7-100	Development
81	Tlea polyphemus, egg	30	53-76	Survival

363. OPTIMAL TEMPERATURES AND HUMIDITIES FOR PHYSIOLOGICAL FUNCTIONS: ARTHROPODS (Concluded)

Several ranges represent extremes reported by different investigators.

	Arthropod	Temperature °C	Optimal Humidity %	Function
	Orthoptera			
82	Carausius morosus, egg	15-21	100	Development
83	Grasshopper, clear-winged (Camnula pellucida), egg	27	60-90	Development
84	Grasshopper, Rocky Mountain (Melanoplus mexicanus), egg	22-37	80-90	Survival
85	Locust, desert (Schistocerca gregaria), egg	30	100	Survival
86	nymph	37.8	55-70	Development
87	adult	37.8	50-60	Oviposition
88	Locust, migratory (Locusta migratoria), nymph	32.2-37.8	60-70	Development
89	adult	37.8	60-75	Oviposition
90	Flea, oriental rat (Xenopsylla astia), larva	17-35	80-94.8	Survival
91	Flea, oriental rat (X. cheopis), larva	22-35	80-90	Survival
92	Flea (X. brasiliensis), larva	22-27	80-95	Survival
	Thysanoptera			
93	Thrips, onion (Thrips tabaci), larva	10-35	75-85	Survival
	Thysaura			
94	Firebrat (Thermobia domestica) egg	37	76-85	Survival
95	nymph	37	84	Development
96	adult	37	84	Oviposition
	Siphonaptera			

364. HEAT EXCHANGES AND ACTIVITY LIMITS IN HOT ENVIRONMENTS: MAN

Basic equation for maximum energy expenditure with heat balance is $M=R+C+E_{max}$, where values are in Cal/sq m body surface per hour; M = body heat production (metabolic rate); R = radiation heat exchange; C = convective heat exchange; E_{max} = maximum evaporative exchange from wet skin. E_{max} is always negative; R and C are positive when heat moves toward the body, and negative when away from the body.

	Environment	Exposure Values: Wind Velocity km/hr	Dry Bulb °C	Relative Humidity %	Vapor Pressure[1] mm/Hg	Clothing Type[2]	Heat Exchange Values: Convection (C)[3] Cal/sq m/hr	Radiation (R)[4] Cal/sq m/hr	Evaporation (E_{max})[5] Cal/sq m/hr	Metabolic Rate Limit (M)[6] Cal/sq m/hr
1	Wet tropics, shade	0.9	31	90	11	None	-13	-18	-72	105
2	Wet tropics, shade	0.9	31	90	11	Light	-7	9	-54	52
3	Wet tropics, shade	8.0	31	90	11	None	-42	-18	-150	210
4	Wet tropics, shade	8.0	31	90	11	Light	-21	9	-113	125
5	Wet tropics, sun	0.9	31	90	11	None	-13	112	-72	0
6	Wet tropics, sun	0.9	31	90	11	Light	-7	45	-54	16
7	Wet tropics, sun	8.0	31	90	11	None	-42	112	-150	80
8	Wet tropics, sun	8.0	31	90	11	Light	-21	45	-113	89
9	Desert, sun	0.9	44	10	35	None	32	172	-230	26
10	Desert, sun	0.9	44	10	35	Light	16	69	-172	87
11	Desert, shade	0.9	44	10	35	None	32	42	-230	155
12	Desert, shade	0.9	44	10	35	Light	16	21	-172	135
13	Desert, sun	8.0	44	10	35	None	94	172	-476	210
14	Desert, sun	8.0	44	10	35	Light	47	69	-357	240
15	Desert, shade	8.0	44	10	35	None	94	42	-476	340
16	Desert, shade	8.0	44	10	35	Light	47	21	-357	390
17	Glass forming[7]	3.7	38	42	21	None	21	255	-220	0
18	Glass forming[7]	3.7	38	42	21	Light	11	128	-165	26
19	Heated chamber	0.9	115	3	19	Light	267	530	-124	0

/1/ Vapor pressure of skin assumed to be saturated at 35°C (42 mm Hg), minus ambient vapor pressure under prevailing conditions of exposure.
/2/ Clothing type: light = underwear shorts, cotton shirt with sleeves, cotton trousers, shoes and stockings or equivalent, offering 0.5 clo protection (1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr; a business suit = 1 clo). /3/ For the nude body, $C=3.7\sqrt{V}\,(Ta-35$ where V is wind speed in km/hr, 35 is assumed skin temperature, and Ta is ambient temperature in °C. Light clothing is assumed to reduce convective exchange by 50%. /4/ For the nude body, $R=3.9\times10^{-8}(T_s{}^4-T_a{}^4)$ where T_{sk} and T_a are in degrees absolute and T_{sk} is assumed 308°A. Solar heat load on nude skin is taken as 130 Cal/sq m/hr. Light clothing is assumed to decrease nominal solar heat load by 60% and radiant exchange with hot or cool walls by 50%. /5/ For the nude body $E_{max}=8.3\,V^{0.37}.\Delta VP$, where V is air movement in km/hr; VPvapor pressure. For the lightly-clad body, it is assumed that evaporation from the skin is reduced by 50%, but that half is, nevertheless, evaporated from the clothing surface where the heat removed is 50% efficient for skin cooling; this gives an assumed net efficiency of sweating equal to $0.75\times E_{max}$ determined for the nude body. /6/ Limit for sustained activity. Expenditure of 50-70 Cal/sq m/hr is involved in sedentary activities; 80-110, light physical work; 120-190, moderate work; 200-290, moderately hard work; 300-390, hard work; 400 and above, very hard work tolerated for prolonged periods only by fit, trained subjects. /7/ Radiant heat.

365. TEMPERATURE CHARACTERISTICS: VARIOUS HOMEOTHERMIC ANIMALS

\+ = present; - = absent.

	Animal	Rectal Temperature: Normal °C	Min °C	Max °C	Critical Air Temperature[1]: Low °C	High °C	Temperature Regulating Mechanisms: Sweating	Shivering	Panting	Thermoneutrality Zone[2] °C —
1	Man	37	22	44	17-22	32	+	+	-	23-34.5
2	Cat	37.2-39	17	42		32.2	-	+	+	10-30
3	Cow, Brahman	38		41.1		32	-		+	10-27
4	Cow, dairy	38-39		42.8	-40	21-27	-		+	4.4-15.6
5	Dasyurus	36.3		40		35-40	-	+	-	24-30
6	Dog	39	17	42.8	-40	29	-	+	+	-40 to 30
7	Donkey	36-38					+			
8	Echidna	28-29	25.5	39-40		35	-	+	-	26-37
9	Elephant	35.9-36.7					-	+		
10	Goat	40								13-21
11	Guinea pig	38.5-39.9	21		-15	29.5			+	30-31
12	Hamster	37	2.2					+		
13	Horse	38					+	+		
14	Marmot	34-39	3	42.1	27.5	30	-	-		28
15	Monkey	38	20	42.7		30-32	+			27-30
16	Mouse	35.2-37.8	12.5		13.14	31.5				30-33
17	Platypus	32.5	25.5	35.3	15	35-40	-	+	-	22-35
18	Rabbit	39.6	20	41.7	-7	28-30	-		+	-5 to 30
19	Rat	35.8-37.6	1.5-16	43	-7	28.5	-	+	-	28-29
20	Sheep	38		42		41-43	+		+	25-27
21	Sloth	33-34.4	20	40	15	35		-	+	
22	Squirrel	35.5-38.4	0-2	42.3						7-37
23	Swine	38-39.6		41.7		29.5	-		+	
24	Chicken	40-42	25-27	45	-34	32.2	-	+	+	16-35
25	Pigeon	42-43	20	47	-40					26-37

/1/ Air temperature at which the first indication of a change in rectal temperature occurs in the unanesthetized animal. /2/ Range of air temperature over which the metabolic rate is lowest and constant in the unanesthetized animal.

366. HEAT PRODUCTION UNDER CONTROLLED ENVIRONMENTAL CONDITIONS: VARIOUS ANIMALS

	Animal	Temperature °C	Heat Production Cal/sq m/24hr[1]
1		15.3	1254
2		19.7	1043
3	Rat	25.0	826
4		30.0	744
5		34.0	1178
6		15.1	1050
7		20.0	913
8	Guinea pig	24.8	784
9		29.8	601
10		35.3	716
11		14.6	1741
12		20.0	1037
13	Mouse	24.9	953
14		29.9	879
15		35.3	1099
16		18.0	1.2[2]
17	Reptile	26.0	2.1[2]
18		32.0	3.2[2]

/1/ Lines 1-15. /2/ Cal/kg/24 hr.

367. EFFECTS OF ENVIRONMENTAL TEMPERATURE CHANGE: MAN, DOMESTIC ANIMALS

Values are for resting state.

	Animal	Variable	Increase of Environmental Temperature			Decrease of Environmental Temperature			
			Single Exposure Response		Repeated or	Single Exposure Response		Repeated or
			General	15-20°C Inc.	Continued Exposure	General	15-20°C Dec.	Continued Exposure
1	Man	Blood volume	Increase		Increase			Decrease
2		Cardiac output	Increase		Return toward normal	Decrease		Return toward normal
3		Food intake	Decrease	Variable	Decrease	Increase	Variable	Increase
4		Heart rate	Increase	5/min	Return toward normal	Decrease	-5/min	Return toward normal
5		Heat production	0 or slight +[1]		Some decrease	Increase	50 to 100 Cal[2]	Increase
6		Manual skill	Deteriorates		Return toward normal	Deteriorates		Return toward normal
7		Packed cell volume	Slight decrease	-2 to 3%	Decrease	Slight increase	2 to 3%	Increase
8		Rectal temperature	Increase	0.5 to 1°C	Return toward normal	Decrease	-1 to 2°C	Return toward normal
9		Skin temperature	Increase	10 to 15°C	Return toward normal	Decrease	-10 to 15°C	Return toward normal
10		Output of urine	Decrease	-200 to 500[3]	Sustain low level	Increase	200 to 500[3]	Sustain high level
11		Blood flow[4]	Decrease		Return toward normal	Increase		Return toward normal
12		Water intake	Increase	400[3]	Sustain high level	Decrease	-400[3]	Sustain low level
13	Cattle	Food intake	Decrease	to 60% normal		Increase		Sustain high level
14		Heart rate	Decrease	-15/min	Sustain low level	Increase	5 to 10/min	Sustain high level
15		Heat production	Decrease		Lasting decrease	Increase	10 Cal/kg/dn	Sustain high level
16		Rectal temperature	Increase	-1 to 2°C	Return toward normal	0 or slight ±[5]		Normal level
17		Respiration rate	Increase	20 to 30/min	Sustain high level	Decrease	-10 to 20/min	Sustain low level
18	Horse	Food intake	Decrease	-15 to 30%	Return toward normal	Increase		
19		Rectal temperature	0 or slight ±[5]		Normal level	0 or slight ±[5]		
20		Respiration rate	0 or slight +[5]		Normal level	0 or slight ±[5]		
21	Sheep	Heart rate	Increase	8/min				
22		Rectal temperature	Increase	1°C				
23		Respiration rate	Increase	100-150/min				
24	Swine	Food intake	Decrease		Continued low level			
25		Heart rate	Increase	10/min				
26		Rectal temperature	Increase 2	2 to 3°C				
27		Respiration rate	Increase	150-200/min				
28		Water intake	Increase		Continued high level			

/1/ No change or slight increase. /2/ Per sq m/hr. /3/ ml/da. /4/ Visceral. /5/ Little or not change.

368. EFFECTS OF HYPOTHERMIA: MAMMALS

Part I: PHYSIOLOGICAL VALUES

A = anesthetized; N = unanesthetized; C = curarized; R = restrained.

State	Variable	Body Temperature, °C					State	Variable	Body Temperature, °C					
		20	25	30	35	37-39			20	25	30	35	37-39	
	Man							Guinea pig (concluded)						
1	N Metabolic rate, Cal/sq m/hr				200	60	33	R O_2 consumption, cu mm/min/g		13	25	35	20.8	
2	A Metabolic rate, Obe/Est		1.58	1.46	2.82	1.00	34	R Ventilation rate, % of normal		75	125	170	100	
3	A Respiratory volume, L/min		9.6		12.7	19.4	8.7							
4	A Respiratory quotient		0.68		0.75	0.77	0.88	Hamster						
5	A Blood HbO_2 capacity, mM/L		10.8		9.73	9.2	8.0	35	N Heart rate, min	190	260	330	380	
6	A Blood HbO_2 content, %		93.0		96.7	95.9	97.2	36	N O_2 consumption, ml/kg/min	38	50			
7	A Blood total CO_2, mM/L		20.0		13.5	18.4	21.5	37	N Respiratory rate, min	120	122	110	90	
8	A Blood pH		7.22		7.31	7.29	7.4	38	Perfused heart rate, min	47	73	105	155	
9	A Blood pCO_2, mm Hg		45.2		27.4	42.2	40.7		Rabbit					
10	Heart rate, sinus-atrium, min[1]	40	70		100	145	157	39	C O_2 consumption, ml/kg/hr		200	300		600
	Ventricle, min[1]	10	20			40		40	N Respiratory rate, min	60	20-40[5]	105		200
	Cat							41	N Heart rate, min	20-40	40-70			200
12	N Heart rate, min	50	117	180	220			42	A Plasma volume, ml/kg			28		44
13	N Respiratory rate, min	0	47	55	60			43	A Hematocrit, %			44		41
14	Perfused heart rate, min	53	100	145				44	A Blood volume, ml/kg			50		73
	Dog							45	A Plasma protein, g/100 ml			6.0		4.9
15	A O_2 consumption, ml/kg/hr[2]	90	160	270	390	430		46	A Thoracymate space, ml/kg			170		245
16	A O_2 consumption, ml/kg/hr[3]	72	325	480	340	380		47	A Circulating RBC volume, ml/kg			22		29
17	A Heart rate, min	30	70	125	170	155		48	A Total circulating plasma protein, g/kg			1.7		2.1
18	A Cardiac output, ml/kg/min	18				135		49	A Extravascular CNS space, ml/kg			140		200
19	A Mean arterial pressure, mm Hg	70	110	120	130	125		50	Isolated strium rate, min	30	65	100	145	
20	A Blood viscosity[4]	8.78	7.23	5.52	4.42	3.50			Rat					
21	A Hematocrit, %	60.6	56.9	54.2	54.1	43.9	51	N O_2 consumption, ml/kg/min	8	17	25			
22	A Arterial O_2 content, vol %	21.0				18.6	52	A Heart rate, min	120	195	270	350		
23	A Coronary vein saturation, %	29.0				28.4	53	R Heart rate, min	110	200	300	420	460	
24	A Coronary vein, O_2 content, vol %	8.3				4.8	54	R A-V conduction time, sec	0.08	0.06	0.045	0.04		
25	A Coronary vein, pO_2, mm Hg	8.6				22.2	55	A Respiratory rate, min	18	48	68	66		
26	A Coronary artery-vein diff., vol %	12.7				13.8	56	A Mean arterial pressure, mm Hg	50	130	140	140		
27	A Duration of systole, sec	0.60	0.33	0.20	0.16	0.15	57	A Liver, glycogen, %					4.10	
28	A P-R interval, sec	0.22				0.10	58	A Blood glucose, mg %					138	
29	A Q R S duration, sec	0.09				0.05	59	Perfused heart rate, min	73	120	165	225		
30	A Q-T interval, sec	1.04				0.25		Tissue slices, dry						
31	Perfused heart rate, min			53	167		60	Cerebral cortex, ml/g/hr	2.7	3.8	5.4	7.9	10.2	
	Guinea pig						61	Liver, ml/g/hr	2.3	4.0	5.9	8.3	9.8	
32	R Heart rate, min		125	215	300		62	Heart ventricle, ml/g/hr	3.3	5.1	7.2	8.3	10.0	
							63	Skeletal muscle, ml/g/hr	1.2	1.50	1.9	2.4	3.1	

/1/ Embryo. /2/ Shivering absent; arterial O_2 saturation 90-100%. /3/ Pattern varies in different animals. /4/ Arterial O_2 saturation 95% and above. /5/ "Pseudo-hibernating" state.

368. EFFECTS OF HYPOTHERMIA: MAMMALS (Concluded)

Part II: LOCAL COLD INJURY

	Mammals	Exposure: Medium	Exposure: Conditions °C; min	Results
1	Man, face	Air	-32.5	Cooling rate 2000 Cal/sq m/hr. Average time to freeze: 102 sec.
2	forearm	Copper bar		Highest temp at which freezing occurred: -2.2 to -4.6°C. Super-cooling to -20.4°C observed without freezing.
3	Rat, foot[1]	Liquid[2]	-22	Average time to freeze: 38 sec.
4			-25	Average time to freeze: 11 sec.
5	Rabbit, ear[3]	Liquid[2]	-5; 0.25	Gangrene, loss of 80% exposed area.
6			-5; 0.5	Gangrene, loss of 80% exposed area.
7			-55; 1+	Edema, gangrene, complete loss of exposed area.
8	foot[4]	Liquid[2]	-55; 1	Edema, no gangrene; 92% of animals showed no loss of tissue, but moderate disturbance.
9	Rabbit, foot[4] (concluded)	Liquid[2]	-55; 2	Edema and gangrene; 80% lost all toes.
10			-55; 3	Edema and gangrene; 69% lost complete exposed area.
11	leg[5]	Alcohol	+5; 30	No edema; slight atrophy.
12			0; 30	Little edema; moderate atrophy and temporary paralysis.
13			-5; 30	Edema, atrophy, temporary paralysis.
14			-10; 30	Edema, atrophy, paralysis, loss of sensation. Muscle necrosis in 50%.
15			-12; 30	Edema, marked muscle necrosis.
16			-15; 30	Edema, muscle and skin necrosis.
17			<-15; 30	Usually complete loss of exposed part.

/1/ Pentobarbital anesthesia; no hair removed. /2/ 150 ml 95% alcohol added to one liter 50% ethylene glycol. /3/ Dial anesthesia; no hair removed. /4/ Dial anesthesia; hair removed by close clipping; immersed to tuberosity at base of 5th metatarsal. /5/ Chemical depilation; no anesthesia; covered with layer of wool fat and rubber boot; immersed to knee.

369. EFFECTS OF HYPOTHERMIA: MAN

Part I: EFFECTS OF BRIEF EXPOSURES TO LOW TEMPERATURES

	Variable	Before Exposure, Air 24°C	After Exposure[1], Air -40°C	Before Exposure, Air 23°C	After Exposure[2], Water 5°C
1	Rectal temperature, °C			37.5	36.5
2	Skin temperature, °C			29.4[3]	8.3[3]
3	Respiratory volume, L/min			9	38.2
4	Oxygen consumption, L/min			0.34	1.74
5	Respiratory quotient			0.81	1.01
6	Metabolic rate, Cal/hr			97	523
7	Heart rate, per min			75	95
8	Systolic pressure, mm Hg			125	144
9	Diastolic pressure, mm Hg			80	93
10	Leucocytes, per cu mm	7000	8300	6600	7950
11	Neutrophils, per cu mm	3500	5000	3370	5720
12	Lymphocytes, per cu mm	2500	2700	2570	1270
13	Monocytes, per cu mm	520	530	265	795
14	Eosinophils, per cu mm	120	105	265	160
15	Basophils, per cu mm	42	40	130	0
16	Hematocrit, %	47.5	49.5	52	50
17	Hemoglobin, g/100 ml blood	16.3	17		
18	Blood, specific gravity	1.057	1.059		
19	Serum protein, g/100 ml	6.8	7.4	5.9	5.9
20	Ascorbic acid, RBC; mg/100 ml	1.7	2		
21	Ascorbic acid, serum, mg/100 ml	1	1.6		
22	Serum chloride, mEq/L	109	100		
23	Serum sodium, mEq/L	144	140		
24	Serum potassium, mEq/L	6.8	8.2		
25	Urine volume, ml/hr	40	100		

/1/ 4 hours exposure. Clothing: U.S. Army Quartermaster winter issue.
/2/ 32-49 minutes after immersion to neck. /3/ Mean temp of immersed parts.

Part II: SURVIVAL TIME FOR IMMERSION IN COLD WATER

#	Probability of Survival	Duration of Immersion and Range of Water Temperature						
			hr	°F	°C		°F	°C
1	Few, if any survivors	From	1.2	30	-1.1	To 3.0	46	7.8
2	50% survive		0.5	35	1.7	2.3	52	11.1
3	All survive		0.7	50	10.0	2.0	70	21.1

Part III: ESTIMATES OF TIME (HOURS) FOR MAXIMUM SAFE LOSS OF STORED BODY HEAT UNDER COLD CONDITIONS

80 calories is estimated safe loss of stored body heat by an adult. Effectiveness of clothing insulation, measured under static conditions, is reduced by penetrating force of wind.

	Air Movement ft/min	Effective Insulation clo[1]	Air at 0°C: Body at: Rest	Air at 0°C: Body at: 3 mi/hr	Air at 0°C: Body at: 4 mi/hr	Air at -40°C: Body at: Rest	Air at -40°C: Body at: 3 mi/hr	Air at -40°C: Body at: 4 mi/hr
1	100	3	0.73	1.90	Infant[2]	0.23	0.34	0.44
2	4000	1	0.58	1.10	1.20	0.22	0.27	0.34
3	100	2	1.17	Infant[2]	Infant[2]	0.53	0.90	2.10
4	4000	2	1.15	Infant[2]	Infant[2]	0.46	0.78	1.60
5	100	3	3.80	Infant[2]	Infant[2]	0.85	2.50	Infant[4]
6	4000	3	3.30	Infant[2]	Infant[2]	0.80	2.20	Infant[4]
7	100	4	10.80	Infant[3]	Infant[2]	1.30	57.0	Infant[4]
8	4000	4	8.80	Infant[3]	Infant[2]	1.20	21.0	Infant[4]

/1/ 1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr. /2/ Complete protection given by 0.6-1.1 clo. /3/ Complete protection given by 1.2-1.7 clo. /4/ Complete protection given by 2.6-2.7 clo.

Part IV: PREDICTED LOWEST AMBIENT TEMPERATURES FOR PROLONGED THERMAL EQUILIBRIUM AND TOLERABLE EXPOSURE

Values are approximations for young adult males and, except where indicated by an asterisk, are from actual observations at Harvard Fatigue Laboratory or Quartermaster Climatic Research Laboratory. Ambient temperature, $T_a = \frac{5.56 - H}{5.56} - H$ where 5.56 is applicable constant for the units of choice; T_a is mean skin temperature, assumed to be 32°C; I is total insulation against $\frac{5.56}{H}$ heat loss by convection and radiation in clo units (1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr); H is total heat available for loss from body by convection and radiation.

	Activity	Environment	Nude: Equilibrium[1] °C	Nude: 1 hr[2] °C	Business Suit (1 clo): Equilibrium °C	Business Suit (1 clo): 1 hr[2] °C	Arctic Clothing (4 clo): Equilibrium °C	Arctic Clothing (4 clo): 1 hr[2] °C
1	Sitting[3]	Calm, shade, sea level	27	17	21	-6	0	-67
2		Wind, 8 km/hr (5 mi/hr); shade, sea level	30	26	24	4	4	-55
3		Wind, 40 kg/hr (25 mi/hr); shade, sea level	31	28	26	12	10	-36
4		Wind, 8 km/hr (5 mi/hr); sunshine[4], sea level	23	19	17	-1	-7	-48
5		Wind, 8 km/hr (5 mi/hr); sunshine, 6 km (20,000 ft) above sea[5]	13*	8*	4*	-19*	-32*	-111*
6	Standing, light work[6]	Wind, 8 km/hr (5 mi/hr); shade, sea level	29	25	20	4	-6	-56
7	Walking, 6 km/hr[7]	Wind, 8 km/hr (5 mi/hr); shade, sea level	25	20	10	-3	-34	-72*
8	Running, 10 km/hr[8]	Wind, 8 km/hr (5 mi/hr); shade, sea level	14	10	-15	-27	-104*	-138*

/1/ In simplest equilibrium state, H is taken as 0.75 M, where M is limit of metabolic rate for sustained activity, expressed as Cal/sq m/hr. (Approximately three-quarters of the heat produced is available for loss by convection and radiation.) /2/ Heat available for loss is 0.75 M+80. (Withdrawal of 80 Cal/sq m from the total body mass can be tolerated with discomfort.) /3/ M=50. /4/ Absorbed solar heat (S) becomes part of H in basic formula. S=130 for nude body, 13.75 for business suit, and 16 for arctic suit. /5/ S increased 70% over values of Fn 4 (greater intensity of solar radiation at altitude). /6/ M=480. /7/ M=180. /8/ M=440.

370. TEMPERATURE RANGES FOR EGG-LARVA DEVELOPMENT: HELMINTHS

Part I: TREMATODES

	Helminth	Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	Clonorchis sinensis	Metacercaria	Tyrode's solution, plus rabbit serum.	37			Survived 2 weeks. No development.
2	Diplostomum flexicaudum		Tyrode's solution, plus lenses from eyes of vertebrates.	Room			Survived and active 52 days. No growth.
3	Fasciola hepatica	Egg	Water.	25	37	5-13	Hatched in 14 days at optimum temperature.
4		Larval stages	In snail.	25			Infection to mature cercariae 38-42 days.
5						16-19	Infection to mature cercariae 67 days.
6	Gynaecotyla adunca	Metacercaria	1% sea water.	40			Matured sexually within 80 hours. Survived 8 days.
7	Microphallus opacus		Ringer's solution and normal saline.	37			Eggs in uterus within 12 hours. Survived 4-5 days.
8						12	Developed slowly.
9	Posthodiplostomum minimum		Dilute Tyrode's solution, plus chicken serum, plus yeast extract.	39			Matured but eggs infertile.
10						5-7	Survived 1 month. No growth.
11	Schistosoma japonicum	Egg	Water.	10-30	37	2	Range for hatching.
12	Zygocotyle lunata	Metacercaria	Water and a wide variety of hosts.			-13 to 7	Metacercariae withstood freezing and thawing 15 hours to 10 days.
13				Body			Matured in bird, mammal.

Part II: CESTODES

	Helminth	Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	Crepidobothrium lönnbergi	Immature worm	Hottinger's broth (modified),	Room			Increased length. Survived 32 days.
2	Diphyllobothrium latum	Egg	Washed feces and tap water.			-10	Eggs non-viable after 48 hours.
3						15	Eggs remained viable 8 months.
4		Plerocercoid	Nutrient agar, plus hog serum.	37.5			Increased size.
5	Echinococcus granulosus	Scolex	Hydatid fluid, plus horse or ox serum.	37-39	42-44	-4 to 0	Volume of bladder increased. Survived 31 days.
6							
7	Ligula intestinalis	Plerocercoid	Peptone broth.			Room	Little activity. Did not mature.
8	Schistocephalus solidus			40			Matured sexually within 7 days. Survived 7 days.
9				16-19			Active. Normal appearance for 300 days. No eggs.
				40			Matured sexually within 48-60 hours. Survived 4-6 days.
10	Taenia crassicollis	Blastocyst	Locke's solution, plus chick embryo extract, plus horse serum.	37.5			Developed to invagination of scolex. Survived 35 days.
11	T. saginata	Egg	Sodium hypochlorite or pepsin-pancreatin, physiological saline.	39			Eggs hatched within 4½ hours.
12						2-5	Remained viable for 13½ weeks.

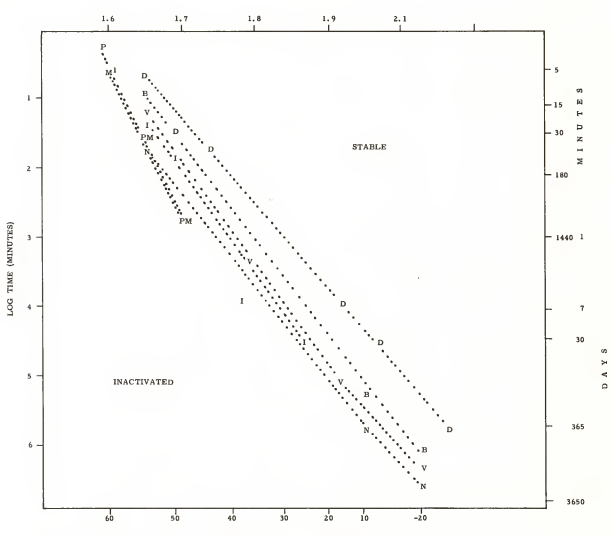
Part III: NEMATODES

	Helminth	Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	Ancylostoma caninum	Egg	Bacteriological agar, plus Bacillus coli.	30	40	12	Range of hatching.
2		Larva		30	37	15	Development range.
3	Ascaris lumbricoides var. suis	Egg	Tyrode's solution.	38-40			Hatched.
4		Larva	Distilled water.	Room			Matured 5 weeks.
5	Dirofilaria immitis	Larva	Dextrose dog serum.	37			Little development. Survived 3-8 days.
6						12	Increased size 2½ times. Survived 2 weeks in ice chest.
7	Eustrongylides ignotus		Bacto-protease-peptone 1.0%; NaCl, 0.85%; glucose, 0.5%.	20			Survived 30 months. Infectivity not established.
8	Haemonchus contortus	Egg Larva	Rabbit kidney, plus liver extract agar, plus ground yeast.	22-27			Eggs hatched 14 days; infective larvae within 26 days.
9	Necator americanus	Egg Larva	"Most favorable conditions."	25-30	37-40	8-10	Range for egg-larvae development.
10	Neoaplectana glaseri	Egg Larva Adult	Veal infusion broth, plus raw liver extract.	21-26	31.8	0	Cycle completed. Survived 44 months.
11	Nippostrongylus muris	Egg	Water.	22-30	35	0-5	Hatched at optimum within 24 hours.
12	Trichinella spiralis	Larva	Simm's solution, plus chicken plasma, plus chick embryo extract.	37			Several molts completed. Few survived 9 days.
13	Trichuris trichiura	Egg	Water.	30	54	-9 to -12	Development range.

371. TEMPERATURES FOR INACTIVATION AND SURVIVAL: ANIMAL VIRUSES

The capacity of animal viruses to infect susceptible cells is destroyed more and more rapidly as the environmental temperature is increased. Thermal inactivation of the infectivity of a virus may be expressed in several ways, as the highest temperature at which there is detectable virus after a selected interval of time, as the longest time at which virus is detectable at a given temperature, or as the number of entropy units. The first two values are dependent on the quantity of virus (number of LD_{50} per ml) in the initial preparation and all three measurements of inactivation depend upon the inherent resistance of the virus particles in the preparation. Substrains composed of heat resistant mutants have been selected for several viruses, and heat resistant and susceptible wild strains are recognized for these and other viruses. Many factors, some well known, modify the thermal inactivation of a virus, *e.g.*, condition of the virus whether wet (inactivation being rapid in a fluid medium) or dry (inactivation of lyophilized virus being slow), the amount of available oxygen (reducing agents increasing stability), the pH of the suspending medium (inactivation being more rapid in basic or acidic preparation than in those in the neutral range), the presence of divalent and monovalent ions (the sodium ion decreasing stability), and admixture with or adsorption to proteins. Most available information has been obtained by using crude preparations in which the contributions of modifying factors are unknown. Tabulation of such data may not, therefore, be meaningful. A figure, therefore, depicting the stability of representative animal viruses in a crude preparation at several temperatures and for varying periods, may be of use to investigators concerned with virus storage, insofar as it suggests the pattern of time-temperature points at which inactivation may occur. On the basis of studies with reasonably pure preparations heat inactivation of virus follows a first order of kinetics.

B = bronchitis; D = distemper; I = influenza A; M = myxomatosis; N = Newcastle disease; P = poliomyelitis; V = vesicular stomatitis.



372. SURVIVAL TIME OUTSIDE THE HOST: PLANT VIRUSES

Common names of viruses are taken largely, but not exclusively, from "Common Names of Viruses Used in The Review of Applied Mycology," Rev. Appl. Mycol. 24:513, 1946. Latin names follow the system of virus nomenclature used by Holmes, "The Filterable Viruses," Williams and Wilkens, Baltimore, 1948.

	Virus	Plant Source of Virus	Conditions of Survival: Medium	Conditions of Survival: Temp °C	Survival Time
1	Alfalfa mosaic (Marmor medicagiois)		Plant juice	Room	8–9 da
2		Tobacco	Plant juice	4	7 da
3		Tobacco	Buffer	4	28 da
4		Cucumber	Dry tissue	1–2	303 da
5	Alsike clover mosaic (M. fastidiens)	Pea (?)	Plant juice	20	24–<48 hr
6	Aster yellows (Chloro-genus callistephi)	Vector	Insect juice	0	24–<48 hr
7		Vector	Insect juice	25	2–<3 hr
8	Bean mosaic (Marmor phaseoli)	Bean	Plant juice	Room	14–<24 hr
9	Bean pod mottle (M. valvolarum)	Bean	Plant juice	18	62–<93 da
10	Bean red node (Annulus orae var. phaseoli)	Bean	Plant juice	18	24–<48 hr
11		Bean	Plant juice	20–25	30–<90 da
12		Bean	Dried tissue	Room (?)	7 mo
13	Bean southern mosaic (Marmor laesiofaciens)	Bean	Plant juice	18	32 wk
14	Bean yellow dot (M. medicaginis var. phaseoli)	Bean	Plant juice	18	72–<96 hr
15		Bean	Dried tissue	8	1 yr
16	Bean yellow mosaic	Bean	Plant juice	Room (?)	28–<32 da
17	Bean yellow stipple (M. flavopunctum)	Bean	Plant juice	18	5–<6 da
18		Bean	Dried tissue	18	80 da
19	Bergerac ringspot (Annulus bergerac)		Plant juice	Room	9–<12 da
20	Broadbean mottle	Broadbean	Plant juice	15	<20 da
21	Bromo-grass mosaic (Marmor graminis)	Bromus inermis	Dried tissue	Room	306 da
22	Carnation mosaic	Carnation	Plant juice	Room (?)	7–<42 da
23	Cauliflower mosaic (M. crucifera-rum)	Cauliflower	Plant juice	22	14–<15 da
24	Celery mosaic (M. umbelllifera-rum)	Celery	Plant juice	Room	6–<7 da
25	Clover red vein mosaic (M. trifolii)	Vicia faba	Plant juice	Room	2–<3 da
26	Cowpea mosaic (M. vignae)	Cowpea	Plant juice	20–25	48–<72 hr
27	Cowpea mosaic (Trinidad)	Cowpea	Plant juice	20	20 da
28	Cucumber green-mottle mosaic	Cucumber	Plant juice	Room (?)	1 yr
29	Cucumber mosaic (M. cucumeris)	Cucumber	Plant juice	Room	2–5 da
30		Sweet corn	Dry tissue	23	58 da
31		Sweet corn	Dry tissue	1–2	669 da
32	Dahlia mosaic (M. dahliae)	Verbesina encelioides	Plant juice	18	28–<35 da
33	Delphinium ringspot (Annulus delphinii)	Cucumber	Plant juice	Room	4–<5 da
34	Dodder latent mosaic (Marmor secretum)	Pokeweed	Plant juice	24	48–<72 hr
35	False garlic mosaic (M. angustum)	False garlic	Plant juice	Room	17–<20 da
36		False garlic	Plant juice	4–5	52 da
37		False garlic	Dried tissue	Room	40–<43 da
38	Hyacinth bean enation mosaic	Hyacinth bean	Plant juice	Room	6 yr
39	Lettuce mosaic (M. lactucae)	Lettuce	Plant juice	Room	48–<72 hr
40	Muskmelon mosaic (M. melonis)	Muskmelon	Plant juice	Room	74–250 hr
41		Muskmelon	Dried juice	Room	72–298 hr
42	Narcissus mosaic	Narcissus	Plant juice	21–24	72–<96 hr
43	Oat mosaic (M. terrestre)	Oat	Dry tissue	1–2	177 da
44	Onion yellow dwarf (M. cepae)	Onio-	Plant juice	29	112 hr
45		Onion	Drying leaves	29	100–<110 hr
46	Orchid mosaic	Cymbidium	Plant juice	Room	7 da
47	Pea enation mosaic (M. pisi)	Pea	Plant juice	Room	4–<5 da
48	Pea mosaic virus (M. leguminosarum)	Bean	Plant juice	22	2–<3 da
49	Pea mottle (M. efficiens)	Pea	Plant juice	25	31 da
50	Pea. mottle (concluded)	Pea	Dried tissue	25	31 da
51	Pea streak, American	Pea	Plant juice	20	24–<48 hr
52	Pea streak, New Zealand (Marmor ineres)	Pea	Plant juice	Room (?)	41 da
53	Pea streak, Wisconsin	Pea	Plant juice	22	16–<32 da
54		Pea	Plant tissue	<0	10–40 da
55	Pea stunt	Pea	Plant juice	22	24–<48 hr
56	Pea wilt (M. repens)	Pea	Plant juice	25	31 da
57		Pea	Dried tissue	25	31 da
58	Potato aucuba mosaic (M. aucuba)	Potato	Plant juice	15	3–<4 da
59	Potato mild mosaic (M. solani)	Potato	Plant juice	Room	2–4 hr
60	Potato mottle (Annulus dubius)	Potato	Plant juice	Room	4–5 mo
61		Nicotiana rustica	Plant juice	16–20	60–360 da
62		Potato	Dried tissue	Room (?)	363 da
63		Tobacco	Dried tissue	Room (?)	386 da
64		Tomato	Dried tissue	Room (?)	50 da
65	Potato spindle tuber (Acrogenus solani)	Potato	Plant juice	10	<48 hr
66		Potato	Dried tissue	Room	7–<17 da
67	Potato vein banding (Marmor upsilon)	Tobacco	Plant juice	Room (?)	5–<6 da
68		Tobacco	Plant juice	20–22	6–18 da
69		Potato	Dried tissue	Room (?)	50 da
70		Tomato	Dried tissue	Room (?)	17 da
71		Tobacco	Dry tissue	1–2	420 da
72	Potato yellow dwarf (Aureogenus vastans)	Nicotiana rustica	Plant juice	25	2–1/2–12 hr
73		Nicotiana rustica	Leaves	-14	1–<7 mo
74		Nicotiana rustica	Partly purified	0	4 wk
75		Nicotiana rustica	Dried leaves	Room	<1 wk
76	Primula mosaic	Primula	Plant juice	22	24–<48 hr
77	Radish mosaic (Marmor raphani)	Radish	Plant juice	22	14–<16 da
78	Rose mosaic (M. rosae)	Cowpea	Plant juice	Room	30–<60 min
79		Cowpea	Plant juice + buffer	Room	6–<24 hr
80	Sugar beet curly top (Ruga verrucosans)	Sugar beet	Plant juice	Room	7–14 da
81		Sugar beet	Ext. alc. precip.	Room	28–<35 da
82		Sugar beet	Dried phloem exudate	Room	10 mo
83		Sugar beet	Dry tissue	Room	8 yr
84	Sugar beet mosaic (Marmor betae)	Sugar beet	Plant juice	21	24–<48 hr
85	Sugarcane mosaic (M. sacchari)	Sugarcane	Plant juice	Room	<7 hr
86	Sunn hemp mosaic, southern		Plant juice	Room (?)	557 da
87	Tobacco broad ringspot (Annulus spterus)	Tobacco	Plant juice	Room	42–<48 hr
88		Tobacco	Plant juice	4	16 da
89	Tobacco etch (Marmor erodens)	Tobacco	Plant juice	Room	5–<13 da
90		Tobacco	Dry tissue	1–2	301 da
91	Tobacco mild dark-green mosaic (M. constans)	Tobacco	Plant juice	5±2	Many yr
92		Tobacco	Dried tissue	Room	Many yr
93	Tobacco mosaic (M. tabaci)	Tobacco	Plant juice	Room	15 mo
94		Tobacco	Dried leaves		52 yr
95	Tobacco mottle	Tobacco	Plant juice	Room (?)	2 da
96	Tobacco necrosis (M. lethale)	Tobacco	Plant juice	21±	About 20 da
97		Tobacco	Dry alc. precip.	Room	6 mo
98		Tobacco	Ab. alcohol	Room	6 mo
99	Tobacco ringspot (Annulus tabaci)	Various suscepts	Plant juice	Room	1–6 da
100		Tobacco	Dry tissue	1–2	393 da

372. SURVIVAL TIME OUTSIDE THE HOST: PLANT VIRUSES (Concluded)

Common names of viruses are taken largely, but not exclusively, from "Common Names of Viruses Used in The Review of Applied Mycology," Rev. Appl. Mycol. 24: 513, 1946. Latin names follow the system of virus nomenclature used by Holmes, "The Filterable Viruses," Williams and Wilkens, Baltimore, 1948.

	Virus	Plant Source of Virus	Conditions of Survival: Medium	Conditions of Survival: Temp °C	Survival Time
101	Tobacco ringspot (Annulus tabaci var. cyamopsidis)	Guar	Plant tissue	5	2-<4 mo
102	Tobacco streak (A. ore)	Tobacco	Plant juice	22	24-<36 da
103	Tomato aspermy	Tomato	Plant juice	20, 5-21, 5	24-<48 hr
104	Tomato black ring	Tomato	Plant juice	Room	7 da
105	Tomato bushy stunt (Marmor dodecahedron)		Plant juice	Room	28-<33 hr
106	Tomato spotted wilt (Lethum australiense)	Tobacco	Plant juice	Room	3-4/2-<4 hr
107	Tulip breaking (Marmor tulipae)	Lily	Plant tissue	Room (?)	2-6 da
108	Turnip mosaic virus (M. brassicae)		Plant juice	20	3-8 da
109	Vigna catjang mosaic	Vigna	Plant juice	24	9-<15 da
110	Wheat mosaic (M. tritici)	Wheat	Dry tissue	1-2	290 da
111	Wheat streak (M. virgatum)	Wheat	Dried tissue	Room	34-40 da

373. EFFECT OF TEMPERATURE ON GROWTH AND SURVIVAL: BACTERIA, RICKETTSIAE, AND COXIELLA

Values are approximate, representing data obtained under widely varying conditions by many investigators. Data may differ from species to species within the same genus, and even with various cultures of the same species. Temperatures given under thermal death time are assumed to be moist heat, but in some cases this has not been specified in the literature source. Values in parentheses are ranges, probably estimate "c" of the 95% range (cf. Introduction).

	Organism	Temperature for Growth[1] °C	Thermal Death °C	Thermal Death min
1	Acetobacter roseum	30-35(10-41)	50	5
2	Achromobacter ichthyodermis	25(-2 to 30)		
3	Actinobacillus lignieresi	37	60	15
4	Actinomyces bovis	37	60	10
5	A. thermophilus	50(28-65)		
6	Aerobacter aerogenes	30(to 42-44)	60	30
7	Agrobacterium tumefaciens	25-28(0-37)		
8	Alkaligenes faecalis	37		
9	Azobacter chroococcum	25-28		
10	Azotomonas indicum	30		
11	Bacillus anthracis	35(to 43)	100^2	10^2
12	B. subtilis	30-37(15-55)	100^2	14
13	B. thermodiastaticus	65(50-75)[3]		
14	Bacteroides fragilis	37		
15	Bacterium erythrogenes	28-35		
16	B. phosphoreum	10(5-25)		
17	Bartonella bacilliformis	28		
18	Brucella spp	37(20-40)	60	10
19	Cellfalcula viridis	20		
20	Cellulomonas biazotea	20		
21	Celivibrio ochraceus	20		
22	Chromobacterium violaceum	25-30		
23	Clostridium botulinum	20-35(18-55)	120^2	5^2
24	C. perfringens	38	100^2	20^2
25	C. tetani	37-38(14-50)	105^2	10^2
26	Coliforms (various)		60-63	30
27	Corynebacterium diphtheriae	34-36(15-40)	54	10
28	Coxiella burnetii	37	62	30
29	Cytophaga hutchinsonii	28-30		
30	Desulfovibrio desulfuricans	25-30(to 40)		
31	Diplococcus pneumoniae	37(18-42)	56	5-7
32	Erwinia carotovora	25-30(4-39)		
33	Erysipelothrix rhusiopathiae	37(15-44)	55	10
34	Escherichia coli	30-37(10-45)	60	10
35	Flavobacterium aquatile	25		
36	Gaffkya tetragena	37(15-39)		
37	Hemophilus influenzae	37(26-43)	50-55	30
38	H. pertussis	37	56	60
39	H. suis	37	60	20
40	Hydrogenomonas pantotropha	28-30		
41	Klebsiella pneumoniae	37(12-43)	55	30
42	Lactobacillus casei	30(10-40)		
43	L. thermophilus	50-63(30-65)	71	30
44	Leptospira icterohemorrhagiae	25-30(25-37)	56	20
45	Listeria monocytogenes	37	59	10
46	Malleomyces mallei	37(15-43)	55	10
47	Methanobacterium omelianskii	37-40(to 48)		
48	Methanococcus mazei	30-37		
49	Micrococcus luteus	25		
50	M. pyogenes var. albus	37	62	10
51	M. pyogenes var. aureus	37(15-40)	60	20
52	Micromonospora chalcea	30-35	70	5
53	Mizugawanella lymphograinulomatis	35-37	56	10
54	Mycobacterium avium	40(30-44)		
55	M. phlei	37(20-58)	60^3	60^4
56	M. tuberculosis	37(30-42)	65	15
57	Mycoplasa dimorpha	30		
58	Neisseria gonorrhoeae	37(25-40)	55	<5
59	N. meningitidis	37(25-42)	50	<5
60	Nitrobacter winogradskyi	25-28	90	5
61	Nitrosococcus nitrosus	20-25		
62	Nitrosomonas monocella	28		
63	Nocardia asteroides	37	60	60
64	Noguchia granulosis	30(15-37)	57	10
65	Pasteurella multocida	37	60	10
66	P. pestis	25-30(0-45)	55	5
67	P. tularensis	37(24-39)	56	10
68	Pediococcus cerevisiae	25		
69	Propionibacterium freudenreichii	30		
70	Proteus vulgaris	37(10-43)	55	60
71	Protaminobacter alboflavum	30		
72	Pseudomonas aeruginosa	37(0-42)	62	10
73	Rhizobium leguminosarum	25		
74	Rickettsia prowazekii	32-35	56	30
75	Rhodopseudomonas palustris	37		
76	Rhodospirillum rubrum	30-37		
77	Saccharobacterium ovale	34-35(20-37)	54	10
78	Salmonella typhimurium	37(4-46)	55	24
79	S. typhosa	37(4-46)	60	2
80	Sarcina ventriculi	30(10-45)	65	10
81	Serratia marcescens	25-30(to <37)	55	60
82	Shigella dysenteriae	37(10-40)	60	10
83	S. equuli	37	60	15
84	Spirochaeta daxenis	42-52	60	30
85	S. plicatilis	20-25		
86	Sporocytophaga myxococcoides	28-30		
87	Streptococcus pyogenes	37(15-40)	60	15
88	Streptomyces thermophilus	40-45(20-<53)	72-74	10
89	S. griseus	37		
90	Thiobacillus thiooxidans	28-30		
91	Treponema pallidum	37[5]	40	60-180
92	Veillonella parvula	37	55	60
93	Vibrio comma	37(14-42)	55-60	2
94	Xanthomonas campestris	28-30(5-38)		

/1/ In this column optimal values are given first, followed in parentheses by a range in which growth occurs but diminishes rapidly as either extreme is approached. /2/ Applies to spores and is an experimental minimum. It is customary to rely only on autoclaving at 121°C for at least 20 minutes to kill these and related spores. /3/ No growth at 50° but growth at 75°. /4/ Survives. /5/ Has never been cultivated in artificial medium.

374. SURVIVAL TIME AND CONDITIONS: BACTERIA PATHOGENIC TO PLANTS

	Organism	Thermal Death Point °C	Survival Duration, Various Conditions (W = overwinters)[1]
1	Agrobacterium tumefaciens	51	24 mo in soil debris[2], hosts[3]
2	Corynebacterium agropyri	50	12 mo in dried exudate
3	C. fascians	50-57	W in or on seeds
4	C. flaccumfaciens	57.5-60	2.5 yr in seed
5	C. insidiosum	51-52	W in soil debris, hosts[3]
6	C. Michiganense	53	W in or on seeds, soil
7	C. sepedonicum		W in soil[4,5,6]
8	Erwinia amylovora	45.1-49.5	W[7] in soil, insect body, hosts[3]
9	E. atroseptica	48-52	W in soil, insect body[4]
10	E. carotovora	48-51	W in soil, insect body[4]
11	E. tracheiphila	43	W in insect body
12	Pseudomonas caryophylli		W in soil
13	P. coronafaciens	48	W in or on seeds
14	P. gladioli	47	W in tubers, corms
15	P. glycinea	48-49	W in or on seeds
16	P. lachrymans	49-50	24 mo in or on seeds
17	P. maculicola	46	W in or on seeds
18	P. marginata	53	W in tubers, corms
19	P. mori	51.5	W in hosts[3]
20	P. phaseolicola		W in or on seeds

[1] Organism in specified condition survives the winter. [2] W on plant roots. [3] In perennial or biennial hosts. [4] W also in tubers, corms, bulbs, etc. [5] W also in soil debris. [6] W also in dried exudate. [7] In beeswax 1.8 mo. [8] Associated with wheat roots.

	Organism	Thermal Death Point °C	Survival Duration, Various Conditions (W = overwinters)[1]
21	Pseudomonas pisi	50	W in or on seeds
22	P. savastanoi	43-46	W in insect body, hosts[3]
23	P. solanacearum	52	>2 yr in soil
24	P. syringae	51	W in or on seeds[5], hosts[3]
25	P. tabaci	49-51	W in soil debris
26	P. viridiflava	48-50	W in or on seeds
27	Xanthomonas begoniae	49-50	W in hosts[3]
28	X. campestris	51	W in or on seeds[3,5]
29	X. carotae	49	W in or on seeds[3,5]
30	X. citri		W in hosts[3]
31	X. hyacinthi	47.5-49	W in tubers, corms
32	X. juglandis	53-55	W in hosts[3]
33	X. malvacearum	50-51	W in or on seed
34	X. papavericola	52	W in soil debris, hosts[3]
35	X. phaseoli	48-50	W in or on seeds, soil[8]
36	X. pruni	51-52	W in hosts[3]
37	X. rubrilineans	51-52	W in hosts[3,4]
38	X. stewartii	53	W in insect body, seeds
39	X. translucens hordei	50	W in or on seeds
40	X. vesicatoria	56	W in seeds, soil[6]

375. EFFECTS OF TEMPERATURE ON GROWTH AND SURVIVAL: FUNGI

Part I: PLANT PATHOGENS

	Species	Temp for Growth[1] °C	Method of Overwintering
	Phycomycetes		
1	Albugo candida	10(1-20)S	Soil; crucifers
2	Peronospora effusa	8-10(3-30)S	Soil; spinach
3	P. parasitica	8-12(to 29)S	
4	P. tabacina	15-23(1-29)S	Plant debris
5	Physoderma zeae-maydis	28-29(23-30)S	Soil; plant debris
6	Phytophthora infestans	20(7-30)C	Soil;tubers
7	Plasmodiophora brassicae	25-27(10-30)S	Soil
8	Plasmopara viticola	25-28(8-35)S	Buds; leaves
9	Pseudoperonospora cubensis	20	
10	Phythium debaryanum	27-30(5-35)C	Soil
11	Rhizopus nigricans	25-30(7-35)C	Soil
12	Sporoguspora subterranea	20-23(12-35)	Soil
	Ascomycetes		
13	Ceratostomella ulmi	22-27(5-40)C	
14	Claviceps purpurea	22-26C	Soil; among seeds
15	Dibotryon morbosum	37(?)	Twig knots
16	Diplocarpon rosae	16-21	Plant debris
17	Endothia parasitica	25-30(4-40)C	Cankers
18	Erysiphe graminis	15-20(5-29)S	Plant debris
19	Gibberella zeae	20-30(3-37)C	Plant debris; soil
20	Glomerella gossypii	25(18-33)	Soil; seed coat
21	Monilinia fructicola	24(0-32)C	Mummy
22	Physalospora malorum	20(10-30)	Cankers; plant debris
23	Podosphaera leucotricha	19-20(10-28)S	Leaf and flower buds
24	Sphaerotheca humuli	37(?)	Plant debris
25	Taphrina deformans	20(10-30)C	Plant debris; bark
26	Venturia inaequalis	20(4-32)C	Plant debris
	Basidiomycetes		
27	Armillaria mellea	25(15-30)C	Soil
28	Cronartium ribicola	12-18(5-25)S	Pine; Ribes
29	Fomes ignarius	30-32(to 42)C	Wood
30	Gymnosporangium juniperi-virginianae	20-25(6-32)S	Redcedar
31	Puccinia antiirrhini	10(5-30)S	Plant debris
32	P. coronata	17-22(2-35)S	Plant debris
33	P. graminis	12-20(2-35)S	Wheat
34	P. triticina	16-20(2-31)S	Wheat
35	Tilletia caries	15-20(4-29)S (1-25)C	Soil; seed coat Soil; seed coat
36	Uromyces cariophyllinus	14(4-29)S	Plant debris
38	Ustilago avenae	20-28(4-35)S	Soil; within seed
39	U. tritici	18-26(6-34)C	Soil; within seed
41		20-25(5-35)S	Within seed
42	U. zeae	20-25(8-34)C	Within seed
		25-30(6-40)S	Soil; plant debris
	Fungi Imperfecti		
43	Alternaria solani	26-28(1.5-45)C	Soil; plant debris
44	Botrytis cinerea	20-25(0-30)C	Apple fruit
45	Cercospora beticola	25-30(6-34)C	Plant debris
46	Cladosporium carpophilum	19-28(2-33)C	Cankers

(continued on next page)

[1] Dealrable temperature for growth, with range (where known) in parentheses, followed by a symbol for the type of growth: C = in culture; S = spore germination.

Part II: ANIMAL PATHOGENS AND RELATED SAPROPHYTES

Data are for artificial culture, under humidity conditions favoring growth.

	Species	Temp for Growth[1] °C	Thermal Death °C	Thermal Death min
1	Absidia corymbifera	28-40(20-46)[37] [20]		
2	Achorion castellani			
3	Actinobacillus lignieresi	37(min 20)[37]	62	10
4	Allescheria boydii	25-30(15-45)[30] [34]	56	80
5	Aspergillus bronchialis	25-45(max >50)[40]		
6	A. fumigatus	25-37[36-38]		
7	A. nidulans	25-37(max <40)[37]		
8	A. niger	25-30[25-30]	60	60
9	Blastomyces brasiliensis	Yeast phase	37	60
10	B. dermatitidis	25-33(8-40)[31]	56	60
11	Yeast phase	35-37[35]	56	60
12	Candida albicans	24-40(<20->40)[30-37]	60	10
13	C. guilliermondi	25-37[30-37]		
14	C. krusei	25-37[30-37]		
15	C. tropicalis	25-37[30-37]	60	10
17	Castellania hashimotoi	[22-25]		
18	Cephalosporium gramulomatis	Room to 37	53	5
19	C. recifei	Room [25-30]		
20	Cladosporium gougerotii	25-37		
21	C. sphaerospermum	Room (min <18)		
22	C. trichoides	Room to 30[30]		
23	C. mansoni	25-35[30-32]		
24	Coccidioides immitis	25-37(max <42)[30-37]	60	4
25	Corynebacterium acnes	37[30-<45][37]	60	10
26	C. tenuis	30-37[about 37]		
27	Cryptococcus neoformans	25-37 (<17-40)[25-30]	50	10
28	Debaryomyces kloeckeri	30-35(3-37)		
29	D. laedegaardi (D. hildegaardi)	25(5-37)		
30	Endomyces pulmonalis	33-37(5-<41)		
31	Epidermophyton floccosum	25-30(min <18)[27±]	50	10
32	Geotrichum candidum	25-37	56	60
33	G. iasavi	22-25		
34	Hansenula anomala	(0.5-42)		
35	Histoplasma capsulatum	22-30(10-40)[25-30]	55	15
36	Yeast phase	34-37(<34->43)[37±]	55	30
37	H. farciminosum	25-37(15-40)[37]		
38	Hormodendrum compactum	25-37[37]	100	15
39	H. dermatitidis	Room to 30 (max <43)[20-30]		
40	H. pedrosoi	25-37[37]	100	15
41	Madurella grises	Room to 37[30]		
42	Microsporum audouini	25-30(max 38)[25-30]	60	60
43	M. canis	25-32(max 40)[30-32]	70	10
44	M. gypseum	25-30(max 38)[25-30]	60	60
45	Nocardia asteroides	25-37[37]	70	5
46	N. brasiliensis	Room to 37	60	60
47	N. caprae	Room to 37[33-37]		
48	N. farcinica	30-40(min >24)[37]	70	10
49	N. intracellularis	37[37.5]	60	10

(continued on next page)

[1] Dealrable temperature for growth, with range (where known) in parentheses, and optimum growth temperature in brackets.

375. EFFECTS OF TEMPERATURE ON GROWTH AND SURVIVAL: FUNGI (Concluded)

Part I: PLANT PATHOGENS (Concluded)

	Species	Temp for Growth[1] °C	Method of Overwintering
	Fungi imperfecti (concluded)		
47	Colletotrichum lagenarium	22-24(6-35)C	Soil
48	C. lindemuthianum	20-23(4-35)C	Within seed
49	Diplodia zeae	30(10-35)C	Soil; within seed
50	Fusarium culmese var. oxysporium	20-30(5-37, 5)C	Soil
51	F. lycopersici	24-30(5-38)C	Soil
52	F. vasinfectum	28-30(10-38)C	Soil
53	Helminthosporium gramineum	15-20 C	Seed coat
54	Phomopsis citri	24-28(9-34)C	Plant debris
55	Phyllosticta solitaria	25-30(5-35)C	Soil debris
56	Thymatotrichum omnivorum	29(18-36)C	Soil; roots
57	Septoria apii-graveolentis	22-24(14-25)C	Plant debris; seed coat
58	Thielaviopsis basicola	17-33	Soil
59	Verticillium albo-atrum	21-26(8-31)C	Soil
	Mycelia sterilia		
60	Rhizoctonia solani	31(8-40)C	Soil
61	Sclerotium cepivorum	20-24(5-29)C	Soil

/1/ Desirable temperature for growth, with range (where known) in parentheses, followed by a symbol for the type of growth: C = in culture; S = spore germination.

Part II: ANIMAL PATHOGENS AND RELATED SAPROPHYTES (Concluded)

	Species	Temp for Growth[1] °C	Thermal Death °C	Thermal Death min
50	N. madurae	Room to 37(<20-40)[37]	60	5
51	N. paraguayensis	Room to 37	60	60
52	Phialophore jeanselmei	Room to 37[30]		
53	P. verrucosa	25-37[37]	100	15
54	Pityrosporum ovale	30-37(min <22)[37]	60	30
55	Rhizopus arrhizus	(6-43a)[32.5-35.5]		
56	R. equinus	(min >5)[37-39]	100	20
57	R. oryzae	(7.5-45.5)[31-34]		
58	Schizophyllum commune	(<16->40)[30a]		
59	Scopulariopsis brevicaulis	Room (<6->40)[20-25]		
60	Sporotrichum schenckii	Room to 37[30-37]	59	5
61	Trichophyton concentricum	25-37[37a]		
62	T. ferrugineum	25	60	10
63	T. megnini	25	55	10
64	T. mentagrophytes	25-30(8-40)[30]	60-70	10
65	T. schoenleinii	25-37(min <15)[33]	60	10
66	T. tonsurans	25-37[30]		
67	T. violaceum	25-37[25-30]		
68	Trichosporon beigelii	Room to 37 (max <43)[30-37]		

/1/ Desirable temperature for growth, with range (where known) in parentheses, and optimum growth temperature in brackets.

376. EFFECTS OF TEMPERATURE: PLANT PATHOGENIC FUNGI

Values not in parentheses are "optimum" values in °C; values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: ae = aeciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnospores; s = spores (not specified); sn = sporangia; sc = sclerotia; t = teliospores; u = uredospores; z = zoospores.

	Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point[1]
1	Actinomyces scabies[2]	16-37	25-32(8-40)			14-22(11-31)		
2	Albugo candida[2]	14-20(0-25)[c]	10-13(0-25)					
3	Alternaria brassicae	33-35(1-46)	25-27(2-36)				25-31(2-36)	55
4	A. citri[2]		25				25-30	
5	A. solani[2]	26-28[s](1-45)	26-28(1-45)				24-25	
6	Aphanomyces euteiches		15-34(9-37)	(9-35)			15-30(10-30)	
7	Armillaria mellea[2]		23[s](15-30)	18-22				65[m]
8	Ascochyta pisi	20(10-35)	20-28(0-35)					
9	Aspergillus niger[2]		30-39(7-46)					99[3]; 62[4][s]
10	Basisporium gallarum[2]	20-35(9-35)	24-35(10-40)					
11	Botryosphaeria ribis[2]		28-30(10-35)			18-28(13-33)		
12	Botrytis allii[2]	19-27(3-27)	20-25(3-33)	4-25(4-25+)			15-20(2-40)	
13	B. cinerea[5]	17-25(1-35)	19-25(0-35)	16-30(4-37)			7-25(0-35)	55
14	Calonectria graminicola[2]		20-22(0-33)		0-10(to 20)			
15	Cephalothecium roseae[2]	19-33(9-35)	20-25(5-35)			25(0 to)		
16	Ceratostomella fimbriata		23-29(9-36)				23-27(9-36)	
17	C. ips		27-29(6-35)	27-31(6-35)				52
18	C. ulmi		19-28(5-40)				51-57[s]	
19	Cercospora beticola	26-33(2-35)	24-30(5-40)	24-32(17-34)	21-32			95[3]; 46[4]
20	Cercosporella herpotrichoides		20-23(-5 to 30)			5-9		
21	Choanephoridea cucurbitae	15-20	30(9-35)	20(10-25)				
22	Cladosporium carpophilum		19-28(2-33)					
23	C. cucumerinum		20-21(0-32)		20(to 35)			
24	C. fulvum[2]	18-26(0-33)	16-26(0-34)	20-26(2-35)			21-25(7-29)	70[3]
25	C. malorum		25			20-25		
26	Claviceps purpurea	18-22[ae]	22-30	17-21				
27	Coccomyces hiemalis		20-24(4-28)	12-16(4-28)	8-28			
28	Colletotrichum circinans	20-26(4-32)	26(2-32)				20-30	
29	C. lagenarium	22-32(4 to)	22-23(6-35)		20-28			
30	C. lindemuthianum[2]	20-32(0-42)	18-30(0-42)	12-15(4-28)			25(6-33)	
31	Coniothyrium wernsdorffiae	16-17(0-27)	20-21(-1 to 26)				10-16(to 27)	
32	Corticium vagum[5]	20-32(8-36)[sc]	20-33(0-44)	18-21			9-30(1-36)	60[sc]
33	Cronartium ribicola	12(5-19)[ae]; 10-18(0-21)[b]; 12-18(0-21)[t]; 14[s-28][u]						
34	Dasyscypha willkommii	15-27(<13-31)	18-23					
35	Deuterophoma tracheiphila	18-20(15 to)	(10-28)	12-28[c]; 12-24[p]				
36	Diplodia zeae	30[p]	24-32(10-36)	25-30[p]			21-32(15 to)	
37	Endothia parasitica[2]	21[as]; 15-32[p]	18-30(4-40)	16-27(2-38)[as]; 30[p]				
38	Erysiphe graminis	18[as]; 12-21(<5-29)[c]	10(0-25)		20			
39	E. polygoni[5]			15-24(<8-30)[c]	15-25 or 24-32[x][p]			
40	Fomes applanatus[2]		27-30(15-35)					65[m]
41	Fusarium conglutinans		20-30(5-35)				16-28(12-34)	
42	F. lini[2]	12-30(7-35)	18-30(5-37)				15-21(12-38)	
43	F. lycopersici[2]		24-30(5-38)				27-29(21-33)	
44	F. oxysporum[5]		15-32(4-40)				14-32(>5 to >38)	57

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state.
/5/ Fungus exhibits extreme variability among different strains or in different hosts.

Values not in parentheses are "optimum" values in °C; values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: ae = aeciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnospores; s = spores (not specified); sa = sporangia; sc = sclerotia; t = teliospores; u = urediospores; z = zoospores.

	Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point[1]
45	Fusarium solani martii[2]	13-25(5-37)	18-34(5-39)			21-34		
46	F. vasinfectum[2]		25-35(5-40)	27-38			17-33((10-35)	
47	Gibberella zeae[5]	30(5-32)[as]; 24-28(4-32)[c]	20-30(3-37)	20-27(to 37[as]; 20-28(4-34)[c]			24-28(8-39)[6]	>65[as]
48	Gloeosporium venetum	22-26(11-32)	20-26(11-31)					
49	Glomerella gossypi		25-29(10-38)			<24		>95[3], 51[4][c]
50	G. rufomaculans	19-36(3-26)	33-38(9-38)			38		
51	Guignardiabidwellii		20-30	20-25(9-35)[p]				>60[s]
52	Gymnosporangium juniperi-virginianae[2]	24(6-32)[ae]; 16(8-28)[b]; 22-29(4-32)[t]					16-19(10 to)	
53	Helminthosporium turcicum		28-30(7-35)	20-28(11-33)		<30		
54	Hypochnus centrifugus[2]		28-35(8-41)	27-35			20-35(2 to)	
55	Lentinus lepideus		27-28(9-40)			<24		>105[3], >60[4][m]
56	Macrophomina phaseoli[2]		31(8-42)				20-40(12 to)	55
57	Merulius lacrymans[2]	22-25	20-26(4-32)					50-55[m]
58	Monilinia fructicola		24-27(0-32)					
59	Mycogone perniciosa		21-28(8-32)				15-21	>42
60	Mycosphaerella rubi	23(2-32)[as]; 23(2-32)[p]	20-23(2-32)					
61	Nectria cinnabarina	17-20(5-30)[as]; 20-25(20-35)[c]	21(3-33)					
62	Neofabraea malicorticis	15-25(0-30)	20(0 to <30)			20(0 to)		
63	Nigrospora oryzae	30(10-47)	30(10-35)					>67[3], 56[4][s]
64	Ophiobolus graminis[2]		19-28(5-35)				12-24(9-32)	
65	O. miyabeanus[2]	25[as]; 25-30 (2-41)[c]	24-32(5-40)	25-28[as]; 20-30 (5-38)[c]			25-30(16-40)	
66	O. sativus[2]	22-32(6-39)[c]	25-33(1-37)	15-28(10-30)[c]			22-30(8-35)	54
67	Penicillium expansum		25-27(0-30)			25(0 to)		
68	Peronoplasmopara cubensis[2]	15-22(1-32)[c]		15-22(7-30)			16-22(10-30)	
69	P. humuli	17-20[c]; 20-22 [o]		15-20(0-28)[c]; 17-20[s]	18-22(4-30)			
70	Peronospora parasitica	8-12(to <29) [c]	8-12(to 29)		3-8			
71	P. tabacina	15-23(1-29)	to 20	21-22(to 26)	11-25(5-30)			
72	Phomopsis citri	20-27(16-33)	24-38(4 to <40)	20(10 to <28)	20-25(15-30)			
73	Phyllosticta solitaria	25-30(5-39)	25-30(5-35)	19-30				
74	Phymatotrichum omnivorum		30	21-32(18-36)				46-51
75	Physoderma zeae-maydis	28-29(23-30)						>80
76	Phytophthora cactorum	25-27[c]	20-36(5-38)				20-25(9-30)	
77	P. cinnamomi[2]		20-30(5-33)	21-29(to 35)				
78	P. citrophthora[2]	28-30; 15-18	25-38(5-37)		20-21			
79	P. infestans[5]	4-20(1-30)	15-25(2-35)	16-23			10-13[7]	45[m]; 25[s]
80	P. parasitica[5]	25-27	20-35(5-44)				21-25	
81	Pyricularia oryzae	25-30(16-35)[c]	25-30(8-40)	18-30(10-35)			24-28(to 34)[6]	51[c]; 52-55[m]
82	Plasmodiophora brassicae	25-30(6-27)					25(9-30)	
83	Plasmopara viticola[2]	25-35(5-35)[8][c]; 23-35(11-33)[o]		18-22(8-30)			18-25(9 to <30)	
84	Polystictus versicolor[2]		25-32[9]			27-32		>70[m]
85	Pseudopezixa ribis	12[as]; 20[c]	20(<4 to 32)	(1-32)[as];8-24 (<4 to <32)[c]				
86	Puccinia coronata[2]	12-22(0-35)				12-17(7-30)		
87	P. glumarum[2]	10-20(2-29)[u]		10-16(0-20)[u]			10-15	
88	P. graminis[5]	5-20(<5 to >30) [ae],15-20[b]; 12-20(5-30)[t];5-25(2-35)[u]		12-18[p]			12-21(to 26); 20-25 (10-30)[u]	
89	P. helianthi	18(6-28)[t],18(<5 to >28)[u]					(10 to)	
90	P. sorghi	15-18(4-32)[u]					18-20(<8 to 32)[u]	
91	P. triticina[2]	10-26(2-32)[u]			20(2-31)[u]	15-22[u]		
92	Pyrenophora graminea		18-30(3-35)				10-18(to 24)	52[c],55[m]
93	P. teres	20[as]; 20-25 [c]	23-30(3-33)	5-30[c], 10-30 [p]	15-35			45[c], 55[m]
94	Pythiacystis citrophthora		25-27(9-32)			18-28(6-32)		46[s]
95	Pythium debaryanum[5]		24-33(5-40)				30-35[10]	
96	P. ultimum		25-35(2-42)				12-21(2-35)	
97	Rhizopus nigricana[2]	19-41(2-41)	20-36(2-40)	16-30(7-32)			6-28(0-36)	55[s]
98	Sclerospora graminicola	18-30(5-35)[c]; 20-34(10-38)[o],14-18[as]; 25-27(8-30)[z]		17-27(5-35)[as]	17-20(11-34)[o]			40[c], 118[3], 53[4][o]
99	Sclerotinia americana	23[c]						
100	S. fructigena	21-25(10 to) [c]	24[27(3-33) 18-25(5-33)	28-33(5-30)			(5 to <35)	52
101	S. libertiana	(3-31); (to 30)[as]	22-25(0-33)	20-25		18-23(0 to >33)		60[ac]
102	S. sclerotiorum[2]	25(3-30)[as]	22-25(0-33)				17-24(0-28)	50[ac]
103	Septoria api		16-27(10-27)	16-25				

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state. /5/ Fungus exhibits extreme variability among different strains or in different hosts. /6/ Value also reported as 8-16 (to 28). /7/ Also 18-32(3-37). /8/ Also 10-16(2-27). /9/ Also 15(0-40). /10/ Also 15-30, or 5-8.

376. EFFECTS OF TEMPERATURE: PLANT PATHOGENIC FUNGI (Concluded)

Values not in parentheses are "optimum" values in °C, values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: as = asciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnospores; s = spores (not specified); ss = sporangia; sc = sclerotia; t = teliospores; u = uredospores; z = zoospores.

	Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point[1]
104	Septoria lycopersici		25(2-34)	25(15-27)				53[s]
105	S. tritici	2-32	20-24(3-32)					
106	Synchytrium endobioticum	12-20(5-30)			16-18(0-30)			85[2][ss]
107	Taphrina deformans		<20-20(10-30)				13-17(10-21)	46[m]
108	Thielaviopsis basicola		23-32(7-37)				17-23(15-32)	
109	Tilletia laevis	16-20(4-36)	20		5-10(to 25)			
110	T. tritici	15-20(0-36)	20(>1 to <25)		6-12(4-22)			
111	Trametes pini		20-25(10-40)					65-70[m]
112	Urocystis cepulae	15(4-28)[m], 15-20(9 to >32)[s]	>18(>9 to 28)				10-25(10-28)	
113	Uromyces trifolii	15-20(6-30)[ae] 17(7 to <30)[t];9-25(<3 to >33)[s]						
114	Ustilago avenae	15-30(4-35)[s], 15-28(0-35)[t]	18-26[6-34]		18-22(7-32)			45-53
115	U. hordei[2]	10-30(0-35)	16-26(<-1 to <35)					43-48
116	U. nuda[2]	20-29(0-34)	20-25(<10-35)					>42[s]
117	U. tritici[2]	22-30(0-35)	24-30(6 to >35)	19-24	23-25(10-30)			45-48
118	U. zeae	25-34(5-40)[t], 20-26 (to 40)[s]	18-26(10-34)		27-35			106[3],52[4][s]
119	Venturia inaequalis	13-22(0-35)[as], 14-25(2-31)[c]	20(<4 to <32)				19(6-24)	
120	Verticillium albo-atrum		16-31(4-37)	23(8-31)		21-25		

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state.

377. TEMPERATURE CHARACTERISTICS: PLANTS

Part I: TEMPERATURE TOLERANCE EXTREMES: ALGAE

Most values in this table are based on observations of algae growing under natural conditions where it is difficult to determine the true temperature of the habitat. Moreover, light absorption may raise the temperature of an algal mass above that of its surroundings. Values, therefore, should be interpreted with caution. * = temperature for maximum growth rate. Where values are given for general groups it is implied that these hold for some but not necessarily all species in that group.

	Species	Maximum for Habitat[1]	Maximum Tolerated	Minimum Tolerated
		Temperature, °C		
1	Cyanophyta (blue-green)		85	
2	40 non-thermal spp		40	
3	Anabaena sp	40		
4	A. variabilis	35*		
5	Anacystis nidulans	61*		
6	A. thermalis	42*		
7	Chroococcus sp	57		
8	C. minutis fuscus	46		
9	C. yellowstonensis	41		
10	Cylindrospermum stagnate	44.1		
11	Gloeocpsa stegophilia	38		
12	Lyngbya sp	65		
13	L. cutealis			Below -17
14	Mastigocladus laminosus	65		-19
15	Microcystis elabens			Below -17
16	Nostoc kihlmani			Below -17
17	N. muscorum	32.5*		
18	N. sphaericum	30		
19	Oscillatoria amphibia	50		
20	O. filiformis	85.2[2]	85.2[3]	59
21	O. formosa	50		
22	O. geminata	45		
23	O. okeni	44		
24	O. proboscides	47		
25	O. tenuis tergestina	44		
26	Phormidium bijahensis	60-62*	85.2[3]	38
27	P. geysericola	75*	85	58
28	P. laminosum	75*	85	58
29	P. tenue	47.2		
30	Rivularia globiceps	26.4		

	Species	Maximum for Habitat[1]	Maximum Tolerated	Minimum Tolerated
		Temperature, °C		
	Cyanophyta (blue-green) (concluded)			
31	Scytonema mirabile			Below -17
32	Synechocystis thermalis	62.2		
33	Synechococcus eximius	79*	84	70
34	S. vulcanus	70*	85	46
35	S. vulcanus bacillarioides	64*	70	57
36	Chlorophyceae (green)		50	-18 to -20[4]
37	Ankistrodesmus falcatus			Below -17
38	Chaetomorpha linum		35	-2 to -7
39	Chlamydomonas nivalis		10	-36
40	Chlamydobtris thermalis		72-74	
41	Cladophora hamosa		35	Below -7
42	C. laetevirens		35	Below -7
43	C. prolifera	30-35	-2 to -7	
44	C. rupestris			-16.8 to -20
45	Cosmarium conspersum			Below -17
46	Desmidium quadratum			Below -17
47	Enteromorpha intestinalis			-18 to -20[4]
48	Euastrum sublobatum			Below -17
49	Protococcus botryoides	80		
50	Ulothrix sp		17	
	Chrysophyta			
51	Bacillariophyceae (diatoms)		50.7	-11
52	Nitzschia putrida		30	-11
53	Chrysophyceae (golden brown)		40.2	
54	Xanthophyceae (yellow-green)		32.5	
55	Phaeophyta (brown)		30	-18 to -20[4]
56	Fucus vesiculosus		30	-18 to -20[4]
57	Rhodophyta (red)			-18 to -20[4]
58	Bangia fuscopurpurea			-18 to -20[4]
59	Porphyra hiemalis			-18 to -20[4]

/1/ Highest temperature reported for natural habitats. /2/ Optimum temperature, 79°C. /3/ Highest recorded temperature for algal growth. /4/ Based on observations of algae in polar seas; not certain that algae were actually growing.

Part II: COLD TOLERANCE: MARINE ALGAE

After 10 hr controlled exposure recorded in western Sweden. + = living; - = dead.

	Species	Temperature, °C					
		-2.9	-4.0	-5.7	-7.8	-10.7	-16.8	-18 to -20
	Red Algae							
1	Trailella intricata	-	-					
2	Laurencia pinnatifida	+	-					
3	Delesseria sanguinea	+	-					
4	D. sinuosa	+	+	-				
5	Ceramium rubrum	+	+	-				
6	Chondrus crispus	+	+	+	+	-	-	-
7	Nemalion multifidum[1]	+	+	+	+	+	+	+
8	Bangia fuscopurpurea	+	+	+	+	+	+	+
9	Porphyra hiemalis	+	+	+	+	+	+	+
	Brown Algae							
10	Laminaria saccharina[2]	+	+	+	-	-	-	-
11	L. digitata[3]	+	+	+	+	-	-	-
12	L. saccharina[4]	+	+	+	+	+	-	-
13	Pylaiella litoralis	+	+	+	+	+	-	-
14	Fucus vesiculosus	+	+	+	+	+	+	+
15	F. serratus	+	+	+	+	+	+	+
16	Ascophyllum nodosum	+	+	+	+	+	+	+
	Green Algae							
17	Cladophora rupestris	+	+	+	+	+	+	-
18	Enteromorpha intestinalis	+	+	+	+	+	+	+

/1/ Prostrate protonematal stage in winter. /2/ One year old.
/3/ Young thallus. /4/ Old thallus; plant several years old.

Part III: TEMPERATURE TOLERANCES: MARINE ALGAE

After 12 hr controlled exposure recorded at Naples. + = living; - = dead; O = not examined.

	Algae	Temperature, °C						
		-7	-2	1 to 2	27	30	35	42
	Intertidal Zone							
1	Bangia fuscopurpurea	+	+	+	+	+	+	-
2	Cladophora bertolini	+	+	+	+	+	+	-
3	C. hamosa	+	+	+	+	+	+	-
4	C. lactevirens	+	+	+	+	+	+	-
5	C. spinulosa	O	+	+	+	+	+	-
6	Polysiphonia pulvinata	+	+	+	+	+	+	-
7	Porphyra leucosticta	+	+	+	+	+	-	-
	Low Water Level							
8	Antithamnion cruciatum	-	+	+	+	+	-	-
9	Callithamnion granulatum	-	O	O	+	-	-	-
10	Ceramium berneri	-	-	-	+	+	-	-
11	Chaetomorpha linum	-	+	+	+	+	+	-
	Depth							
12	Acrosorium uncinatum	-	-	+	+	-	-	-
13	Callithamnion scopulorum	-	-	-	+	-	-	-
14	Ceramium strictum	-	+	+	+	+	-	-
15	Cladophora prolifera	-	+	+	+	+	-	-
16	C. ramellosa	-	O	O	+	-	-	-
17	C. utriculosa	-	+	+	+	+	-	-
18	Griffithsia furcellata	-	-	-	+	-	-	-
19	G. schousboei	O	O	O	+	+	-	-
20	G. setacea	-	-	-	+	-	-	-
21	Nitophyllum punctatum	-	-	+	+	-	-	-
22	Pleonosporium borreri	-	-	+	+	-	-	-
23	Plocamium coccineum	-	-	+	+	-	-	-
24	Taonia atomaria	-	O	O	+	+	-	-

Part IV: WORLD-WIDE DISTRIBUTION: THERMAL ALGAE

	Temp °C	Cyano-phyceae	Chloro-phyceae	Conju-gatae	Rhodo-phyceae
		Number of Species			
1	17-30	41	9	4	1
2	30-35	38	7	2	0
3	35-40	62	8	6	0
4	40-45	37	5	1	1
5	45-50	35	4	0	0
6	50-60	37	3	2	0
7	60-75	10	0	0	0

Part V: MAXIMUM TEMPERATURE TOLERANCE: LICHENS

Values are for air-dry tissue. Those in parentheses are for water-soaked tissue. After treatment of air-dry tissue for 30 min, a 50% decrease in respiration was observed.

	Lichen	Temp °C
	Hygrophilic	
1	Alectoria implexa	72-73
2	A. ochroleuca	72
3	A. sarmentosa	70-74
4	Lobaria pulmonaria	73(36.5)
5	Usnea dasypoga	71-74(<35)
6	U. florida	70
7	Cladonia foliacea convoluta	92-94
8	C. pocillum, C. pyxidata	101
9	C. rangiformis pungens	99(46.5)
10	Umbilicaria cylindrica	95
11	U. hirsuta	100
12	U. pustulata	98(45.5)
13	U. vellea	98-100(44)

Part VI: TOLERANCE TO EXTREMES OF HEAT AND COLD: MOSSES

	Moss	Temp °C
	Maximum Temperature[1]	
	Most sensitive of 50 spp tested	
1	Frullania dilatata, Lake Garda	70-75
2	Gymnomitrium obtusum	65-70
3	Plagiothecium curvifolium	65-70
4	P. denticulatum	70-75
	Maximum Temperature[1] (continued)	
5	Least sensitive of 50 spp tested	
	Barbula gracilis, Montpellier	110-115
6	Ceratodon purpureus	100-105
7	Grimmia trichophylla	105-110
8	Pleurochaete squarrosa, Lake Garda	100-105
	Maximum Temperature[1] (concluded)	
9	Pleurochaete squarrosa, Montpellier	105-110
	Minimum Temperature[2]	
10	Majority of 30 spp tested	-10 to -20
11	Least sensitive of 30 spp tested[3]	-20 to -30

/1/ Injury observed after 30 min heating in dry state over phosphorus pentoxide. /2/ Duration, 18 hr in turgescent state during winter. /3/ Species include: Ceratodon purpureus, Dicranum scoparium, Grimmia pulvinata, Plagiothecium denticulatum, P. undulatum.

Part VI: TOLERANCE TO EXTREMES OF HEAT AND COLD: FLOWERING PLANTS

	Plant	Temperature °C
	Maximum Temperature[1]	
	Hydrophytes	
1	Elodea (Elodea callitrichoides)	38.5
2	Elodea (E. canadensis)	39-39.5
3	Parrot's feather (Myriophyllum verticillatum)	40
4	Vallisneria (Vallisneria spiralis)	41.5
	Shade plants	
5	Oxalis (Oxalis acetosella)	40.5
6	Impatiens (Impatiens parviflora)	41.5
	Herbaceous plants: xerophytic habitat	
7	Cetersch (Cetersch officinarum)	48
8	Fescue (Festuca glauca)	50.5
9	Germander (Teucrium chamaedrys)	48
10	Germander (T. montanum)	48.5
11	Hawkweed (Hieracium pilosella)	50.5
12	Iris (Iris chamaeiris)	49.5
13	Mullein (Verbascum thapsus)	48.5
14	Opuntia (Opuntia sp)	53
15	Pink (Dianthus carthusianorum)	48
16	Sedum (Sedum acre)	48.5-49.5
17	Sedum (S. reflexum)	49.5-50
18	Sedum (S. spurium)	48.5
19	Thorn apple (Datura stramonium)	47
	Minimum Temperature	
20	Achimene (Achimenes patens)[2]	1-5
21	Coleus (Coleus spp)[3]	>1
22	Episcia (Episcia cupreata)[2]	1-5
23	Gloxinia (Gloxinia grandiflora)[2]	1-5
24	Peperomia (Peperomia argirilia)[3]	>1
25	Sultana (Impatiens sultani)[3]	>1
	Winter-conditioned Plants[4]	
	Cereal and field crops[5]	
26	Barley (Hordeum vulgare)	-10 to -15
27	Beet (Beta vulgaris)	-5 to -7
28	Cabbage (Brassica oleracea capitata)	-8 to -11
29	Oat (Avena sativa)	-9 to -12
30	Potato (Solanum tuberosum)	-2 to -3
31	Rape (Brassica napus)	-9
32	Rye (Secale cereale)	-15 to -25
33	Wheat (Triticum aestivum)	-10 to -22
	Tree fruits: flowers[6]	
34	Apple (Pyrus malus)	-1.7 to -2.2
35	Apricot (Prunus armeniaca)	-0.6 to -2.9
36	Cherry (Prunus sp)	-1.1 to -2.2
37	Peach (P. persica)	-1.1 to -2.8
38	Pear (Pyrus communis)	-1.1 to -2.2
39	Plum (Prunus sp)	-0.6 to -2.2
	Tree fruits: fruit set	
40	Apple (Pyrus malus)	-1.1 to -2.2
41	Apricot (Prunus armeniaca)	0 to -2.2
42	Cherry (Prunus sp)	-1.1 to -2.2
43	Peach (P. persica)	-1.1 to -2.8
44	Pear (Pyrus communis)	-1.1 to -2.2
45	Plum (Prunus sp)	-0.6 to -2.2
	Trunk cortex	
	Apple (Pyrus malus)	
46	In January	-29
	Flowering period	-8
	Apricot (Prunus armeniaca)	
48	In January	-21
49	Flowering period	-6 to -7
	Cherry (Prunus sp)	
50	In January	-23
51	Flowering period	-8
	Deciduous trees (29 species)[7]	
52	Buds opening (May 15)	-3 to -4
	Resting buds (January)	
53	Majority of spp tested	-20 to -22
54	Filbert (Corylus avellana)	Below -20
55	Walnut (Juglans regia)	Below -20

/1/ More than 50% of test plants (50+ species) uninjured after 30 min heating in an atmosphere of saturated humidity. In dry atmosphere maximum tolerated temp is 2-5°C greater. /2/ Endures exposure up to 24 hr in an atmosphere of saturated humidity. Further exposure results in injury to leaves and, later, shoot apex. /3/ Injury observed after 28 hr at 0.3-1°C. /4/ Plants previously conditioned to low temp. /5/ Experimental temp for conditioned tissues. Data may be useful for estimating winter-cold resistance. /6/ Reported to endure -2.3 to 2.7°C for 30 min. /7/ 12-hr exposure.

Part VII: LOW TEMPERATURE TOLERANCE: FLOWERING PLANTS

Winter-conditioned plants were exposed to experimental temperatures indicated in winter column; actively growing plants (in summer season) were observed under experimental temperatures shown in summer column.[1]

	Plant	Temperature Winter °C	Temperature Summer °C
	Evergreen species (Riva-Cardasee)		
1	Chamaerops (Chamaerops humilis)	-12 to -14	-10 to -12
2	Fortune's palm (Trachycarpus fortunei)	-12.5 to -15	-10 to -13
3	Laurel (Laurus nobilis)	-10 to -10.5	-6
4	Oak (Quercus ilex)	-13 to 13.5	-6
5	Oleander (Nerium oleander)	-9	-4 to -6
6	Olive (Olea europaea)	-12	-6.5
7	Strawberry-tree (Arbutus unedo)	-10	-5 to -8
8	Trifoliate-orange (Poncirus trifoliata)	-18 to -22	-12 to -16
9	Viburnum (Viburnum tinus)	-11 to -12	-4 to -7
	Conifers (Riva-Cardasee)		
10	Cedar (Cedrus atlantica, C. deodara)	-15 to -17	-6 to -8
11	Cypress (Cupressus sempervirens)	-14 to -18	-7 to -9
12	Pine (Pinus pinea)	-11 to -14	-5 to -7
	Evergreen dwarf Alpine shrubs (Innsbruck)		
13	Bear-berry (Arctostaphylos uva-ursi)	-29	-9
14	Heath (Erica carnea)	-18.5	-4.5
15	Heather (Calluna vulgaris)	>-28	-5
16	Loiseleuria (Loiseleuria procumbens)	-35	-9
	Rhododendron (Rhododendron ferrugineum)		
17	In protected position	-15	-5
18	In exposed position	-25	-5
19	Rhododendron (R. hirsutum)	-28.5	-5.5
	Conifers of Alpine Timberline (Innsbruck)		
20	Pine (Pinus cembra)	below -39	-10
21	Pine (P. montana)	-35	-6
22	Spruce (Picea excelsa)	-38	-8 to -9
	Conifers of Moscow Mountains (Idaho)[2]		
23	Fir (Abies grandis)	-45 to -55	-15
24	Pine (Pinus ponderosa)	-50 to -60	-15
	Field weeds		
25	Chickweed (Stellaria media)	-9.7	-2.5
26	Ironweed (Veronia tournefortii)	-10.8	-4.3

/1/ 15-20% injury observed after 2-3 hr at indicated temp, and slow freezing and thawing for several hr with mature 1-2 yr old leaves of adult plants. No injury observed at 1-2°C higher temp. Resting buds reported to be more cold resistant to low temp than leaves. /2/ Slight injury observed after exposure of a few min.

Part IX: TEMPERATURE RANGE OF METABOLIC ACTIVITY: PLANTS

Temperature values, unless otherwise specified, are lower and upper limits within which the specified activity was observed.

	Plant	Activity	Temp °C
	Algae		
1	Chlamydomonas nivalis	Photosynthesis	-10 to 10
	Chlorella (Chlorella pyrenoidosa)		
2	Strain Emerson	Growth	25^1, 29^2
3	Strain Tx 71105	Growth	39^1, 41^2
4	Strain Emerson	Photosynthesis	32^3, 39^4
5	Strain Tx 71105	Photosynthesis	41^3, 45^4
6	Strain Emerson	Respiration	30^3, >45^4
7	Strain Tx 71105	Respiration	41^3, >50^4
8	Dunaliella salina	Protoplasmic streaming	-19 to 40
9	Mastigocladus laminosus	Growth	5 to 60
10	Nitella syncarpa	Protoplasmic streaming	0^5
11	Phaeosphaera perforata	Growth	4 to 10
	Lichens		
12	Reindeer (Cladonia rangiferina)	Photosynthesis	-20 to 38
	Flowering Plants		
13	Barley (Hordeum vulgare)	Growth	5^5
14	Bean, kidney (Phaseolus multiflorus)	Carbohydrate translocation	1 to 6^5
15	Cherrylaurel (Prunus laurocerasus)	Photosynthesis	-6 to 37
16	Chickweed (Stellaria media)	Photosynthesis	-10 to 35
17	Coconut (Cocos nucifera)	Growth	10 to 30
18	Corn (Zea mays)	Growth	9.5 to 46
19		Chlorophyll formation	13 to 14^5
20	Date (Phoenix dactylifera)	Photosynthesis	10 to 54
21	Fir, arctic (Abies excelsa)	Photosynthesis	-40 to 30
22	Morning glory (Ipomoea spp)	Respiration	10 to 60
23	Pea (Pisum sativum)	Growth	-2 to 40
24	Pumpkin (Cucurbita pepo)	Growth	14 to 46^5
25		Protoplasmic streaming	11 to 12^5
26	Wheat (Triticum aestivum)	Growth	5 to 42
27	Wheat (T. ferrugineum)	Chlorophyll formation	2^5

/1/ Optimum temperature for continuous growth. /2/ Maximum temperature for continuous growth. /3/ Optimum temperature in experiments of short duration. /4/ Maximum temperature in experiments of short duration. /5/ Minimum temperature.

Part X: LOWER TEMPERATURE LIMITS OF PHOTOSYNTHESIS

Lines 1, 2, and 4 apply to the Alpine timberline (1900 m), Innsbruck in May; all others at 600 m in April.

	Plant	Temperature, °C							Plant	Temperature, °C						
		-1	-1	-2	-3	-4	-5	-6		-1	-1	-2	-3	-4	-5	-6
1	Pinus cembra	+	-					→	6	+	+	+	-			→
2	Arctostaphylos uva ursi			-				→	7	+	+	+	50%	-		→
3	Buxus japonica	+	+	50%	-			→	8	+	+	+	50%	-		→
4	Picea excelsa	+	+	-				→	9	+	+	+	+	-		→
5	Erica carnea	+	+	50%				→	10	+	+	+	50%	-		→
									11	+	+	+	+	67%	50%	-

Part XI: TEMPERATURE REQUIREMENTS FOR SPECIFIC CROPS

Data adapted from "Climate and Man," Yearbook of Agriculture, 1941. Values are broad generalisations and do not take into account such variables as day-night temperature differentiation, variety differences, physiological responses for which the optima are different from those for growth, and, in some instances, length of time during which temperatures above or below tolerance limit may persist. However, in many cases, data in this part may be correlated with that in other parts of this table and in other tables in this series.

	Plant	Specification
		Very Hardy Cool-season Crops
1	Beet, garden (Beta vulgaris)[1]	Optimum vegetative growth at 16-21°C (60-70°F); tolerates repeated mild freezing temperatures at market stage. At >21°C (>70°F) growth is retarded.
2	Broccoli, sprouting (Brassica oleracea botrytis)	Similar to cabbage. Yield and quality reduced at mean temperature of >16°C (>60°F).
3	Brussels sprouts (B. oleracea gemmifera); collards, kale (B. oleracea acephala)	Tolerant to freezing temperatures at market stage; cool temperatures improve quality. Intolerant to monthly means of >21°C (>70°F).
4	Cabbage (B. oleracea capitata)[2]	Optimum vegetative growth at 16-21°C (60-70°F). At >21°C (>70°F) plants remain vegetative, with slow, abnormal growth. Plants in bead-stage are tolerant to frost, intolerant to freezing temperatures. Young, stocky, well-hardened plants, with stem 5-8 mm in diameter, survive winter temperature of -18°C (0°F) for short periods; larger or smaller plants are less hardy; larger surviving plants are likely to produce flowering stalks, instead of heading, in spring. Plants in active growing condition are intolerant to sudden freezing temperatures.
5	Spinach (Spinacia oleracea)	Optimum vegetative growth at 10-16°C (50-60°F). Fall-sown plants having a few well-developed leaves at the onset of cold weather are tolerant to freezing temperatures for many weeks; small seedlings and plants approaching maturity are less hardy. Sudden warm temperatures in spring terminate vegetative growth of plants overwintered or spring planted. At 21-27°C (70-80°F) crinkling and sturdy leaf growth reduced.
6	Turnip (Brassica rapa); rutabaga (B. napus napobrassica)	Optimum temperature similar to cabbage. Immature plants are more tolerant than cabbage to short periods at 4°C (40°F); mature plants more tolerant to mild freezing temperatures. At 24°C (75°F) growth rate is reduced, leaves injured.
		Less Hardy Cool-season Crops
7	Carrot (Daucus carota)	Optimum temperature 16-21°C (60-70°F); in seeding stage is more sensitive to temperature extremes. Leaves are damaged at freezing temperatures. Best color and highest carotene content occur at 10-16°C (50-60°F) (crop yield low). Normal growth does not occur between <10 (<50°F) and >21°C (>70°F).
8	Cauliflower, heading broccoli (Brassica oleracea botrytis)	Optimum temperature 16-21°C (60-70°F); less tolerant to temperature extremes than cabbage. Above 21°C (70°F) leafy, loose, or yellowed curds develop.
9	Celery (Apium graveolens dulce)	Optimum temperature 16-21°C (60-70°F). Treatment at 4-10°C (40-50°F) for 10 days conducive to flowering instead of normal growth. Prompt flowering (under chilled conditions) proportional to age of plant.
10	Lettuce (Lactuca sativa)	Optimum temperature 13-18°C (55-65°F). At 21-27°C (70-80°F) heading is prevented, plants flower. At constant temperature of 21°C (70°F) tip-burn is serious. High temperature conducive to development of bitter flavor. Small immature plants tolerant to mild freezing temperatures but mature plants are injured.
11	Pea, garden (Pisum sativum)	Optimum temperature 13-18°C (55-65°F); more seriously injured by frost than cabbage; slight freezing temperatures may injure or destroy flowers and fruits. At >27°C (>80°F) premature ripening of fruit occurs.
12	Potato (Solanum tuberosum)	Most rapid development of young sprouts at constant temperature of 24°C (75°F), later growth best at 18°C (64°F). At soil temperature of >24°C (>75°F), there occurs excessive branching of young sprouts, shortening of internodes, decrease in segmentation of leaves, diminution in stem diameter. At constant temperature of 20°C (68°F) tuber production is decreased with complete inhibition at 29°C (84°F). Below -1°C (30.2°F) tubers are injured.
		Adapted to a Wide Range of Temperature and Tolerant to Frost
13	Onion (Allium cepa)	Fairly low temperatures best for early stages of growth; for bulbing, fairly high temperatures, 16-21°C (60-70°F). Bulbing is influenced by day length. At 10-16°C (50-60°F) flowers are initiated; at 21-27°C (70-80°F), no flowering.
		Adapted to a Wide Range of Conditions but not Tolerant to Frost[1]
14	Bean (Phaseolus spp)[3]	Optimum temperature 16-21°C (60-70°F).
15	Corn (Zea mays)	Optimum: mean summer temperature 21-27°C (70-80°F), night temperature, >14°C (>58°F). Date of flowering much earlier at 27°C (80°F) than at 21°C (70°F); retarded flowering at 16°C (60°F).
16	Cucumber (Cucumis sativus), Muskmelon (C. melo)	Optimum temperature 18-24°C (65-75°F).
17	Pepper, hot (Capsicum sp)	Tolerates higher temperature than sweet pepper.
18	Pepper, sweet (Capsicum sp)	Temperature requirements are a little higher than those for tomato, but more sensitive to chilly, wet weather in the spring and more tolerant to high summer temperatures. At 27°C (80°F) fruit set poor; constant temperature below 16°C (60°F) or above 32°C (90°F), complete barrenness.
19	Tomato (Lycopersicon esculentum)	Optimum temperature 21-24°C (70-75°F); tolerance extremes, 18-27°C (65-80°F). A constant temperature of 24°C (75°F), almost complete barrenness.
		Warm Region Crops
20	Eggplant (Solanum melongena esculentum)	Minimum temperature 18-21°C (65-70°F).
21	Sweetpotato (Ipomoea batatas)	Very sensitive to frost; minimum temperature 21°C (70°F).
22	Watermelon (Citrullus vulgaris)	Long growing season with high temperatures required.
		Perennial Crops
23	Asparagus (Asparagus officinalis)	Stem elongation rapid at 25°C (78°F), greatly retarded at 11°C (52°F). Early development of lateral branches at 35-40°C (95-105°F).
24	Rhubarb (Rheum rhaponticum)	Injured at -3 to -4°C (25-27°F), but intolerant to high temperatures of southern U.S.A. Development of pink color occurs at low temperatures and green color at high temperatures.

/1/ Cold, wet weather, even though frost-free, is harmful. Should not be planted until monthly means have reached 16-18°C (60-65°F). /2/ Biennial; after first growing period requires a dormant period at low temperature for initiation of flower stalk and flowers. /3/ Includes lima, string and many others.

378. VITALITY TESTS: SEEDS

	Test	Seeds	Specification	Interpretation or Results
			Biochemical Tests	
1	Indigo carmine, 0.05%	Pine	Stain for 2 hr., 20°C.	Embryo uncolored to 1/4 colored = viable.
2	Phenol, 1%	Wheat	Stain for 25 hr., 15°C.	
3	Tetrazolium, 1%	Various spp.	Stain for 24 hr (in dark), 20°C.	Embryo red = viable.
4	$NaHSeO_3$, 2%	Agricultural spp.	Stain for 16 hr + 8 hr with aeration.	
5	Na_2TeO_4	Various spp.	Treat in H_2O for 24 hr, 20°C; remove seed coat; stain for 48 hr.	Embryo black = viable.
6	Meta-dinitrobenzene	Rye, wheat	Oxidation-reduction: treat for 5 hr, 20°C.	Seed purple in NH_3 = viable.
7	KOH	Tropical spp.		Seed discolored = dead.
8	KI, 1.5%	Spruce	Treat for 8 hr, 20°C; then incubate for 24 hr.	Seed deep purple = viable.
9	I, 1%	Pine		
10	Oxidase activity	Various spp.	Crush and treat in 0.1% guaiac resin.	Seed blue or violet = viable.
			Embryo Culture	
12	Nutrient culture	Various spp.	Knop's medium + glucose, agar for 7 da, 20°C.	Growth of embryo directly proportional to actual
13	Filter paper		Moisten with H_2O, 5-10 da, 21-23°C.	germination.
			Physical Tests	
14	Cutting and crushing	Thin, soft coated	Cutting: treat in water.	Seed firm, free from discoloration = viable.
15		Heavy coated	Crushing: stratify for 4 wk.	
16	Visual	Birch	Transparency.	Embryo undeveloped, shrunken = immature.
17		Pine, spruce	Embryo-ratio.	Embryo length-seed length ratio <0.8 = immature.
18	Specific gravity	Pine	In water.	Floating seed = dead.[1]
19		Spruce	In alcohol	
20	Electric conductivity	Grasses	"Blaze current" proportional to viability;	rise in conductivity proportional to % dead seed.
21	Heat of respiration	All species	Aseptic incubation.	Temp. increase proportional to germinative energy.

/1/ Floating seeds are almost invariably non-viable; however, sinking is not necessarily an indication of viability.

379. CONDITIONS FOR SEED GERMINATION: HERBACEOUS PLANTS

	Species	Temp.[1] °C	Duration[2] da	Specifications[3]
	Agricultural Crops			
1	Alfalfa (Medicago sativa)	20	4-7	B, S
2	Barley (Hordeum vulgare)	20	4-7	T, S; prechill[4]
3	Bean, field (Phaseolus vulgaris)	20-30	5-8	R, S
4	Beet (Beta vulgaris)	20-30	3-14	BrH_2O soak[5]
5	Bentgrass (Agrostis tenuis)	20-30	7-28	P; light, KNO_3
6	Bermuda grass (Cynodon dactylon)	20-35	7-21	P; light, KNO_3
7	Bluegrass (Poa pratensis)	15-30	10-28	P; light, KNO_3[6]
8	Buckwheat (Fagopyrum esculentum)	20-30	3-6	B, T
9	Canary grass (Phalaris canariensis)	20-30	3-7	B
10	Clover (Trifolium spp)[7]	17-18	4-7	B, S
11	Corn (Zea mays)	20-30	4-7	R, S
12	Cotton (Gossypium spp)	20-30	4-12	R, S
13	Cowpea (Vigna sinensis)	20-30	5-8	R, S
14	Crotalaria (Crotalaria spp)	20-30	4-10	B, S
15	Dallis grass (Paspalum dilatatum)	20-35	7-21	P; light, KNO_3
16	Fescue (Festuca arundinacea)	20-30	5-14	P; light
17	Fescue (F. elatior)	20-30	5-14	P; light
18	Flax (Linum usitatissimum)	20-30	3-7	B, S
19	Hemp (Cannabis sativa)	20-30	3-7	B
20	Johnson grass (Sorghum halepense)	20-35	7-35	P; light, KNO_3
21	Lespedeza (Lespedeza stipulacea)	20-35	5-14	B
22	Lupine (Lupinus angustifolius)	20	4-10	R, S
23	Mustard (Brassica nigra)	20-30	3-7	P; light, KNO_3[9]
24	Oat (Avena sativa)	20	5-10	T, S; prechill[4]
25	Orchardgrass (Dactylis glomerata)	20-30	7-21	P, S; light
26	Pea, field (Pisum sativum arvense)	20	3-8	R, S
27	Peanut (Arachis hypogaea)	20-30	3-5	B, S
28	Redtop (Agrostis alba)	20-30	5-10	TB, P; light
29	Rice (Oryza sativa)	20-30	5-14	B, T
30	Rye (Secale cereale)	20	4-7	T, S; prechill[4]
31	Ryegrass (Lolium multiflorum)	20-30	5-14	P, TB; light, KNO_3
32	Sesame (Sesamum orientale)	20-30	3-6	P
33	Sorghum (Sorghum vulgare)	20-30	4-10	B, S; prechill[4]
34	Soybean (Glycine soja)	20-30	5-8	R, S
35	Sunflower (Helianthus annuus)	20-30	3-7	T, B
36	Timothy (Phleum pratense)	20-30	5-10	P, TB; light, KNO_3
37	Tobacco (Nicotiana tabacum)	20-30	7-14	P, TB; light
38	Wheat (Triticum spp)	20	4-7	T, S; prechill[4]
39	Wheatgrass (Agropyron cristatum)	20-30	5-14	P, TB; light, KNO_3[10]
	Vegetable Crops			
40	Asparagus (Asparagus officinalis)	20-30	7-21	T
41	Bean (Phaseolus coccineus)	20-30	5-9	R, S
42	Bean (P. lunatus macrocarpus)	20-30	5-9	R, S, C
43	Broadbean (Vicia faba)	17-18	4-14	S, C[8]
44	Cabbage (Brassica oleracea cap.)	20-30	3-10	P, T[11]
45	Carrot (Daucus carota)	20-30	6-28	B

	Species	Temp.[1] °C	Duration[2] da	Specifications[3]
	Vegetable Crops (concluded)			
46	Celery (Apium graveolens dulce)	20-30	10-21	P, TB; light, KNO_3[9]
47	Cucumber (Cucumis sativus)	20-30	3-7	T, S, B
48	Dandelion (Taraxacum officinale)	20-30	7-21	P, TB; light
49	Eggplant (Solanum melongena esculentum)	20-30	7-14	TB
50	Endive (Cichorium endiva)	20-30	5-14	P, TS
51	Kale (Brassica oleracea acephala)	20-30	3-10	B, P[11]
52	Lettuce (Lactuca sativa)	20	7	P; light, prechill[12]
53	Muskmelon (Cucumis melo)	20-30	4-10	B, T, S[13]
54	Okra (Hibiscus esculentus)	20-30	4-21	R
55	Onion (Allium cepa)	20	6-12	B, S
56	Parsley (Petroselinum hortense)	20-30	11-28	B
57	Parsnip (Pastinaca sativa)	20-30	6-28	B
58	Pea, garden (Pisum sativum)	20	5-8	R, S
59	Pepper (Capsicum spp)	20-30	6-14	TB
60	Pumpkin (Cucurbita spp)	20-30	4-7	T, S[13]
61	Radish (Raphanus sativus)	20	4-6	B
62	Rhubarb (Rheum rhaponticum)	20-30	7-21	TS; light
63	Rutabaga (Brassica napus napob.)	20-30	5-14	B
64	Spinach (Spinacia oleracea)	10	7-21	TB[13]
65	Squash (Cucurbita spp)	20-30	4-7	T, S[13]
66	Tomato (Lycopersicon esculentum)	20-30	5-14	B[14]
67	Turnip (Brassica rapa)	20-30	3-7	B
68	Watermelon (Citrullus vulgaris)	20-30	4-14	T, S[13]
	Flowers			
69	Aster, annual (Aster sp)	20	8	TB
70	Balsam (Impatiens balsamina)	20	8	TB; light, KNO_3
71	Canterbury bell (Campanula spp)	20-30	6-12	TB
72	Carnation (Dianthus caryophyllus)	20	8	TB
73	Cornflower (Centaurea cyanus)	15	4-8	TB
74	Cosmos (Cosmos spp)	20-30	3-8	TB; light, KNO_3
75	Dahlia (Dahlia spp)	20-30	4-10	TB
76	Daisy (Chrysanthemum maximum)	20-30	8	TB; light
77	Forget-me-not (Myosotis sp)	20	5-12	TB
78	Hollyhock (Althaea rosea)	20	5-18	B
79	Larkspur (Delphinium spp)	15	10-21	TB
80	Marigold (Tagetes spp)	20-30		TB
81	Nasturtium (Tropaeolum spp)	18	14	R
82	Pansy (Viola tricolor)	20	12	TB
83	Petunia (Petunia spp)	20-30	6-10	P; light
84	Poppy (Papaver orientale)	20	6-12	TB
85	Salvia (Salvia splendens)	20-30	4-12	TB; light
86	Snapdragon (Antirrhinum spp)	20-30	5-12	P; light[15]
87	Stock (Matthiola incana)	20-30	7	TB; light
88	Sweetpea (Lathyrus odoratus)	18	12	R
89	Wallflower (Cheiranthus allioni)	20-30	4-10	TB; KNO_3
90	Zinnia (Zinnia spp)	20-30	3-7	TB; light

/1/ When a range is given, a daily fluctuating temperature is preferred, viz: 16 hours at lower temperature and 8 hours at higher temperature.
/2/ Maximum germination is usually obtained during the time limits as specified; for hard coated seeds an additional 5 days is recommended.
/3/ Substrata: B = between blotters; TB = top of blotters; T = between folded paper toweling; R = rolled towel; S = soil or sand; P = closed petri dish with cotton, blotter or filter paper; C = creped cellulose paper wadding. For KNO_3 treatment, a 0.2% solution, unless otherwise specified, is used to moisten substrata. /4/ Prechill at 5 or 10°C for 5 days. /5/ Soak in water for 2 hours, rinse, blot surface dry. /6/ Use 0.1% KNO_3. Prechill dormant seeds at 10°C for days. /7/ Species include; T. hybridum, T. incarnatum, T. pratense; T. repens, duration of 3-7 days. /8/ Dormant seed: 15°C. /9/ Prechill at 10°C for 3 days. /10/ Prechill at 5 or 10°C for 7 days. /11/ Dormant seed: light, KNO_3; prechill at 5 or 10°C for 3 days. /12/ Prechill at 10 or 15°C for 3 days. /13/ Substrata held somewhat drier than for the average kind of seed. /14/ Dormant seed: light, KNO_3. /15/ Fresh and hybrid seed may require prechilling at 3 or 5°C for 10-20 days.

When shed by the plant, seeds of certain species normally undergo a dormant period before onset of germination. Dormancy may be broken by various appropriate treatments prior to planting. Pretreatments usually include exposure to cold and to moisture, and may also include partial or complete rupture of the seed coat by scarification. If, following pretreatments, conditions for germination are established, maximum germination occurs within the indicated interval.

	Species	Pretreatment[1]		Germination	
		Temp[2] °C	Duration da	Temp[3] °C	Duration da
	Fruit and Nut Crops				
1	Apple (Pyrus malus)	5	75	20-30	60
2	Butternut (Juglans cinerea)	2-7	90-120	20-30	45-60
3	Cherry (Prunus avium and cerasus)	0-5	90-120	20-30[4]	60
4	Chestnut (Castanea dentata)	0-5	90	15-26[4]	30-45
5	Hickory (Carya spp)	-1 to 7	90-150	20-30	30-60
6	Mulberry (Morus rubra)	5	90-120	20-30	30-45
7	Peach (Prunus persica)	2-7	45-90	20-30[4]	60
8	Pear (Pyrus communis)	0-7	60-90	10	45
9	Pecan (Carya illinoensis)	2-7	30-90	20-30	45-60
10	Persimmon (Diospyros virg.)	10	60-90	20-30	40-60
11	Plum (Prunus americana)	5	150	10[5]	60
12	Raspberry (Rubus idaeus)	20-30; then 5[6]	90 90	20-30	30
14	Walnut (Juglans nigra)	3	60-120	20-30	15-40
	Broadleaf Trees and Shrubs				
15	Alder (Alnus rubra)	5[4]	30-60	20-30[4, 7]	30-40
16	Ash (Fraxinus spp)[8]	5	60-90	20-30	40-60
17	Ash (F. excelsior, F. nigra)	20; then 5[6]	60-90 60-90	20-30	30-40
19	Aspen (Populus tremuloides)		20-40		7
20	Barberry (Berberis spp)	0-5	15-40	12-24	40
21	Basswood (Tilia americana)	2-5[9]	110-130	18-29	30-60
22	Beech (Fagus spp)	5	90	20-30	60
23	Birch (Betula pendula)	0-10	30-60	20-30	30-40
24	Birch (B. populifolia)	0-10	60-90	20-30	40
25	Birch (B. papyrifera)	5	60-75	15-32	30-40
26	Birch (B. lenta)	0-5	40-70	15-32	30
27	Birch (B. alleghaniensis)	5	30-60	15-32	30-40
28	Boxelder (Acer negundo)	5	90	10-25	30-60
29	Catalpa (Catalpa spp)			20-30	30-60
30	Cherry (Prunus serotina)	5	90-120	20-30	30
31	Coffeetree (Gymnocladus dioica)	18-30; then 1-5[6]	60-120 60-90	20-30	60-90
33	Cottonwood (Populus deltoides)			20-30	2-6
34	Crabapple (Malus baccata)	5	30	20-30	30
35	Crabapple (M. coronaria)	5	120	10	30
36	Dogwood (Cornus florida)	5	100-130	20-30	20-25
37	Dogwood (C. nuttallii)	0-5	120-200	20-30	40
38	Elaeagnus (Elaeagnus spp)	5	90	20-30	20-40
39	Elm (Ulmus americana)	5	60	20-30	13-60
40	Elm (U. thomasii)			20-30	4-10
41	Elm (U. rubra)	5	60-90[4]	20-30	50-70
42	Eucalyptus (Eucalyptus globulus)			16-21[10]	10-15
43	Hackberry (Celtis spp)	5	60-90	20-30	60
44	Hawthorn (Crataegus mollis)	21-27; then 5[6]	60 75-90	16-27	
45	Honeysuckle (Lonicera tatarica)	Scarification[11] 5	60 30-60	20-30	60-90
47	Hornbeam (Carpinus caroliniana)	2-7	100-120	16-27	45
50	Locust (Robinia pseudoacacia)	Scarification[12]		15-27	10-25
51	Magnolia (Magnolia grandiflora)	5	90-120	15-26[4]	60
52	Maple (Acer macrophyllum)	5	60	20-30[4]	60[4]
53	Maple (A. rubrum)	5	60-75	10-25	30-40
54	Maple (A. saccharinum)			25-30	20-30
55	Maple (A. saccharum)	3-5	60-90	20-30	30
56	Oak (Quercus velutina)	1-5	30-60	18-27	30-50
57	Oak (Q. macrocarpa)	5	30-45	20-30	40
58	Oak (Q. prinus)			18-27	60
59	Oak(Q. robur)			16-25	30-60
60	Oak (Q. rubra)	0-4	30-45	20-30	40-60
61	Oak (Q. coccinea)	0-5	30-60	20-30	60

	Species	Pretreatment[1]		Germination	
		Temp[2] °C	Duration da	Temp[3] °C	Duration da
	Broadleaf Trees and Shrubs (concluded)				
62	Oak (Quercus imbricaria)	0-5	30-60	16-24	30
63	Oak (Q. alba)			20-30	30-50
64	Peashrub (Caragana spp)	Water soaking[13]		20-30	30-60
65	Poplar (Populus spp)			20-30	4-7
66	Rhododendron (Rhododendron spp)			20-30	30-90
67	Rose (Rosa spp)	5[14]	120	20-30[4]	30[4]
68	Serviceberry (Amelanchier spp)	2-5	90-180	20-30	40
69	Sumac (Rhus glabra)	Scarification[15]		20-30	30-60
70	Sweetgum (Liquidambar styraciflua)	5	30-90	20-30	20-60
71	Sycamore (Platanus occidentalis)	2-5	45-60	20-30	15-20
72	Tupelo (Nyssa sylvatica)	-1 to 10	60-90	20-30	30-60
73	Yellow-poplar (Liriodendron tulipifera)	0-10	70	20-30	50-70
	Conifers				
74	Alaska-cedar (Chamaecyparis nootkatensis)	5[4]	60-90[4]	20-30	60
75	Baldcypress (Taxodium distichum)	5	30-60	20-30	30-50
76	Cedar (Cedrus spp)			20-30	30-40
77	Cypress (Cupressus arizonica)	5	60	20-30	30
78	Douglas-fir (Pseudotsuga menziesii)	1-5	30-60	16-30	15-30
79	Fir (Abies spp)[16]	5	60-90	20-30	30-45
80	Fir (A. balsamea)	5	90	20-30	60-120
81	Fir (A. grandis)[17]	5	30-40	20-30	30-45
82	Fir (A. procera)	1-5[4]	40-60	20-30	15-30
83	Hemlock (Tsuga canadensis)	5	60-120	20-30	60
84	Hemlock (T. heterophylla)	1-5	90	11-16	25-30
85	incense-cedar (Libocedrus decurrens)	2-5	60-90	15-27	40-60
86	Juniper (Juniperus scopularum)	20-30; then 5[6]	120 120	20-30	20-30
88	Larch (Larix laricina)	5	30-60	20-30	30-50
89	Larch (L. decidua)	5	60	20-30	35
90	Larch (L. occidentalis)	5	30	20-30	20-30[4]
91	Pine (Pinus spp)[18]			20-30	30-40
92	Pine (P. strobus)	10	30	20-30	30-40
93	Pine (P. jeffreyi)			15-27	60-90
94	Pine (P. taeda)	2-4	30-90	20-30	35-45
95	Pine (P. contorta)			15-27	30
96	Pine (P. palustris)			13-24	35
97	Pine (P. rigida)	5	30	18-27	30
98	Pine (P. echinata)	2-4	30-45	15-27	35-45
99	Pine (P. elliottii)	2-5	15-45	18-30	20-45
100	Pine (P. lambertiana)	2-10	90	16-21	40
101	Pine (P. monticola)	0-5	90	16-27	60-90
102	Port-Orford-cedar (Chamaecyparis lawsoniana)	5[4]	30-60[4]	20-30	60
103	Redcedar (Juniperus virginiana)	25; then 5[6]	30 90	10-25	20-30
104	Redcedar (Thuja plicata)	0-10	30-60	20-30	20
106	Sequoia (Sequoia spp)			15-20	40-60
107	Spruce (Picea marizna)	5	30-60	20-30	20-30
108	Spruce (P. engelmannii)			20-27	50
109	Spruce (P. abies)			20-30	20-30
110	Spruce (P. rubens)	5	30-45	20-30	20-30
111	Spruce (P. sitchensis)	1-5	40	25	15
112	Spruce (P. glauca)	5	60-90	20-30	30-45
113	White-cedar (Chamaecyparis thyoides)	5[4]	30-60	20-30	60
114	White-cedar (Thuja occidentalis)	0-10	30-60	20-30	30

/1/ When no treatment is specified, pretreatment is not required. /2/ When a range is given, the temperature may vary between the limits. /3/ When a range is given, a daily fluctuating temperature, 16 hr at lower temperature and 8 hr at higher temperature, is preferred. /4/ Suggested treatment, experimental data incomplete. /5/ Seeds from southern USA germinate best at 21-27°C. /6/ Treatment at high temperature is followed by treatment at low temperature. /7/ Germination data also applicable to European alder (A. glutinosa), pretreatment not required. /8/ Species include: green ash (F. pennsylvanica), white ash (F. americana). /9/ Prior to stratification soak 3 da in water, surface dry, then digest 40 min in concentrated H_2SO_4 (below 95°C), wash and extract seeds. Place dry seed in concentrated H_2SO_4 for 10-15 min. /10/ Constant temperature between these limits is preferred. /11/ Scarify with concentrated H_2SO_4 (25-36°C) for 1-2 hr prior to planting. /12/ Scarify with concentrated H_2SO_4 (16-27°C) for 20-120 min prior to planting. /13/ Soak seed in water at 21°C for 12 hr prior to planting. /14/ Scarify with concentrated H_2SO_4 for 60-80 min prior to planting. /15/ Scarify with concentrated H_2SO_4 for 1-4 hr prior to planting. /16/ Data applicable to Pacific silver fir (A. amabilis), white fir (A. concolor); for California red fir (A. magnifica), with a duration of pretreatment modified to 60 days. /17/ Data also applicable to Fraser fir (A. fraseri), of Fn 4. /18/ Species include: ponderosa pine (P. ponderosa), red pine (P. resinosa), Scotch pine (P. sylvestris); jack pine (P. banksiana), with duration of germination modified to 15-60 days.

381. RESISTANCE TO WILTING

Plants may grow within a wide range of soil moisture conditions, but at a definite moisture limit, known as the wilting coefficient (permanent wilting percentage), the plant is unable to overcome the resistance of soil to water removal. The wilting coefficient is the moisture content of the soil, expressed as a percentage of dry weight, at the time when the leaves of the plant first undergo a permanent reduction in moisture content (resulting from soil moisture deficiency). At this condition the leaves cannot recover in an approximately saturated atmosphere without the addition of water to the soil. In Part I, free energy values indicate soil's resistance (to removal of water) that plants would have to overcome at various moisture levels. Part II shows that all plants wilt at relatively the same moisture content in a given soil. Sampling error varies with completeness with which the roots contact the soil mass, Cocklebur, for example, may have relatively few coarse roots whereas alfalfa has very many fine absorbing-roots. Part III gives wilting coefficients as determined from small or large soil containers. Part IV demonstrates that repeated wiltings do not increase the ability of plants to take more water from soil. Part V reveals the constancy and recurrence of wilting coefficient in the field; determinations were made in the same orchard for many years. Soil moisture is reduced to essentially the same point annually, and plants do not become more resistant to wilting with increase in age. Differences in root distribution influence wilting percentages. Part VI denotes that wilting coefficient is not affected by evaporation conditions antecedent to wilting, or by soil temperature within the moderate and maximum range likely to be encountered during the growing season. Part VII gives the depths to which the roots of mature crops might exhaust the water supply when grown in a deep, permeable, well-drained soil, having little horizon formation. The survival of certain plants under severe conditions of drought may depend, in part, on the depth of rooting and thoroughness with which the roots permeate soil and not on the capacity to extract water from soil than other plants.

Part I: FREE ENERGY PER GRAM OF WATER: VARIOUS SOIL MOISTURE CONTENTS AT 30°C

	Soil Moisture[1] %	Vapor Pressure mm Hg	Relative Humidity %	Energy[2] ergs
		Fine Sandy Loam		
1	10.5	31.7	99.7	4.40
2	9.3	31.7	99.7	4.40
3	5.9	31.6	99.4	8.82
4	5.4	31.4	98.7	17.70
5	4.6	31.4	98.7	17.70
6	3.0	31.4	98.7	17.70
7	1.7	30.8	96.7	44.68
8	1.6	30.3	95.3	67.55
9	1.2	27.5	86.5	203.12
10	0.9	24.9	78.3	341.95
11	0.8	23.3	73.3	442.40
12	0.7	17.9	56.3	803.43
		Clay Soil		
13	27.0	31.6	99.4	8.82
14	21.6	31.5	99.1	13.25
15	18.6	31.3	98.4	22.16
16	13.1	31.3	98.4	22.16
17	10.9	31.1	97.8	31.12
18	10.8	30.6	96.2	53.78
19	10.1	29.3	92.1	114.47
20	9.6	28.1	88.4	172.93
21	9.0	26.5	83.1	268.83
22	8.7	25.3	79.6	319.72
23	8.5	24.0	75.5	393.40
24	8.4	22.9	72.0	458.96
25	7.9	18.2	57.2	780.22
26	7.8	17.0	53.5	875.57

/1/ Grams water per 100 g soil. /2/ Free energy per g water x 10^6.

Part II: WILTING COEFFICIENT: CLAY SOIL

	Species	Wilting %
1	Alfalfa (Medicago sativa)	13
2	Castor bean (Ricinus communis)	15
3	Cocklebur (Xanthium canadense)	15.6
4	Coleus (Coleus blumei)	14.2
5	Corn (Zea mays)	15
6	Fenugreek (Trigonella foenum-graecum)	15
7	Hollyhock (Althaea rosea)	14.2
8	Jimson-weed (Datura tatula)	15
9	Lettuce (Lactuca sativa)	14.6
10	Mallow (Malva parviflora)	13.4
11	Marigold (Tagetes lucida)	13.6
12	Mung-bean (Phaseolus aureus)	14.7
13	Mustard (Brassica alba)	13.8
14	Okra (Hibiscus esculentus)	14.7
15	Pepper (Piper capsicum)	14.6
16	Petunia (Petunia hybrida)	13.7
17	Pigweed (Amaranthus retroflexus)	14.5
18	Salvia (Salvia splendens)	14.4
19	Sorghum (Sorghum vulgare)	14.2
20	Soybean (Glycine soja)	14
21	Spinach (Spinacia oleracea)	13.7
22	Sunflower (Helianthus annuus)	14
23	Thistle (Silybum marianum)	15
24	Wheat (Triticum aestivum)	13.6

Part III: WILTING COEFFICIENT; VARIOUS SOIL CONTAINERS

	Plants	Soil Container	Wilting %	Availability Ratio[1]
		Oakley Fine Sand (3, 25)[2]		
1	Sunflower	10-quart	1.41	2.33
2	Corn	10-quart	1.35	2.44
3	Sunflower	Small[3]	1.24	2.65
4	Corn	Small[3]	1.36	2.42
5	Miscellaneous[4]	10-quart	3.29	2.55
	Yolo Fine Sandy Loam (16, 80)[2]			
6	Miscellaneous[4]	10-quart	8.67	1.98
7	Miscellaneous[4]	Tank[5]	8.88	1.74
	Yolo Fine Sandy Loam (18, 49)	2		
8	Sunflower	10-quart	9.78	1.89
9	Corn	10 quart	9.67	1.91
10	Sunflower	Small[3]	10.06	1.84
11	Corn	Small[3]	10.33	1.79
	Yolo Silt Loam (21, 35)[2]			
12	Sunflower	10-quart	10.25	2.08
13	Corn	10-quart	10.28	2.08
14	Sunflower	Small[3]	10.38	2.05
15	Corn	Small[3]	10.71	2.00
16	Miscellaneous[4]	10-qt.	5.95	2.15
	Yolo Clay (28, 03)[2]			
17	Sunflower	10-quart	13.35	2.10
18	Corn	10-quart	13.13	2.13
19	Sunflower	Small[3]	14.48	1.94
20	Corn	Small[3]	14.46	1.94
21	Miscellaneous[4]	10-quart	12.65	2.22

/1/ Ratio of moisture equivalent, cf Fn 2, and permanent wilting; indicates the range of available water. /2/ Moisture equivalent, i.e., percentage water content that a soil can retain in opposition to a force 1000 times that of gravity, is enclosed in parentheses. /3/ Cannery cans containing about 550 g soil. /4/ Include cotton, sorghum, guar, mustard, black-eye and mung beans. /5/ Tanks contained 1000 to 2000 lbs soil.

Part IV: WILTING COEFFICIENT: SUNFLOWER

	Soil	Percentages for Successive Wiltings					
		1st	2nd	3rd	4th	5th	6th
1	Oakley fine sand	1.6	1.5	1.5	1.6	1.5	1.5
2	Yolo fine sandy loam	9.5	9.4	9.4	9.3	9.2	9
3	Yolo silt loam	10.7	10.5	10.8	10.7	10.6	11
4	Yolo clay	13.4	13.8	13.8	14	14.3	
5	Plainfield fine sand	1.4	1.4				
6	Fresno sandy loam	3.1	3.1	3.1	3	3	
7	Tehama loam	4.5	4.5	4.4			
8	Placentia loam	5.8	6	6.1			
9	Wooster silt loam	6.2	6	5.8			
10	Madera & Gridley loam	10.5	10.5	10.4	10.5	10.4	
11	Brockton clay loam	11.6	11.4	11.6			

Part V: PERMANENT WILTING PERCENTAGE: END OF GROWING SEASON

	Soil	Wilting Percentages at:									
	Depth	1 yr	2 yr	3 yr	4 yr	5 yr	6 yr	7 yr	8 yr	9 yr	10 yr
		Peach (Prunus persica)									
1	0-3	9.9	8.0	8.7	8.8	8.6	9.2	10.5	10.3	9.8	9.7
2	3-6	8.6	8.0	8.4	7.8	8.0	8.3	9.4	9.6	9.1	8.6
3	6-9	7.9	7.4	7.6	7.7	7.6	7.6	9.1	8.8	7.7	7.4
4	9-12	8.8	7.4	8.3	8.3	7.7					
		Fuji (Prunus americana)									
5	0-3	8.4	9.0	8.7	8.5	8.5	8.4	8.8	8.9	8.8	8.9
6	3-6	7.9	7.8	8.0	7.8	8.0	8.2	8.6	7.8	7.6	8.4
7	6-9	9.8	10.2	9.7	9.9	10.0	9.7	10.3	9.6	10.6	
		Walnut (Juglans sp)									
8	0-3	10.5	10.8	11.0	11.1	10.5	10.5	11.3	11.0	10.4	11.1
9	3-6	11.3	11.2	11.1	10.5	10.7	11.1	11.2	11.1	10.9	11.4
10	6-9	8.4	8.9	9.1	8.7	7.9	8.7	8.8	9.0	9.5	9.5

Part VI: WILTING COEFFICIENT: SHADE AND FULL SUNLIGHT

	Soil	Plant	Wilting %	
			In Shade	In Sun
1	Oakley fine sand	Sunflower	1.3	1.4
2		Corn	1.3	1.4
3	Yolo clay	Sunflower	14	13.7
4		Corn	13.5	14.1
5	Yolo fine sandy loam	Sunflower	11	9.5
6		Corn	9.8	9.9
7	Yolo silt loam	Sunflower	10.4	10.4
8		Corn	10.7	10.6
9	Placentia loam	Sunflower	3.7	4.1
10		Corn	4.6	3.8
11	Sierra sandy loam	Corn	6	6.5
12	Columbia sand	Sunflower	6.3	7.2
13		Corn	6.7	6.5

Part VII: DEPTH OF WATER EXTRACTION: MATURE PLANT ROOTS

	Species	Root Depth Ft
1	Alfalfa (Medicago sativa)	10-15
2	Almond (Prunus amygdalus)	6-9
3	Apricot (P. armenicea)	6-9
4	Artichoke (Helianthus tuberosus)	4, 5
5	Asparagus (Asparagus officinalis)	10
6	Bean (Phaseolus lunatus macrocarpus)	4
7	Beet, garden (Beta vulgaris)	3
8	Beet, sugar (B. vulgaris)	5-6
9	Broccoli (Brassica oleracea botrytis)	2
10	Cabbage (B. oleracea capitata)	2
11	Cantaloupe (Cucumis melo cantalupensis)	4-6
12	Carrot (Daucus carota)	3
13	Cauliflower (Brassica oleracea bot.)	2
14	Celery (Apium graveolens)	2
15	Cherry (Prunus spp)	6-9
16	Citrus (Citrus spp)	6
17	Corn, field (Zea mays)	6
18	Corn, sweet (Z. mays)	3-5
19	Cotton (Gossypium spp)	6
20	Cucumber (Cucumis sativus)	3, 5
21	Eggplant (Solanum melongena)	3
22	Fig (Ficus carica)	5
23	Flax (Linum usitatissimum)	6
24	Grape (Vitis vinifera)	8
25	Hop (Humulus lupulus)	4-6
26	Lettuce (Lactuca sativa)	1.5
27	Milo (Sorghum vulgare)	6
28	Mustard (Brassica juncea)	3.5
29	Olive (Olea europaea)	6-9
30	Onion (Allium cepa)	1
31	Parsnip (Pastinaca sativa)	4
32	Pea (Pisum sativum)	3.5
33	Peach (Prunus persica)	6-9
34	Pear (Pyrus communis)	6-9
35	Prune (Prunus americana)	6-9
36	Pepper (Capsicum frutescens)	3
37	Potato (Solanum tuberosum)	3
38	Pumpkin (Cucurbita pepo)	6
39	Radish (Raphanus sativus)	1.5
40	Spinach (Spinacia oleracea)	2
41	Squash (Cucurbita pepo)	3
42	Sudan grass (Sorghum sudanense)	>6
43	Tomato (Lycopersicon esculentum)	6-10
44	Turnip (Brassica rapa)	3
45	Strawberry (Fragaria spp)	3-4
46	Sweet potato (Ipomoea batatus)	4-6
47	Walnut (Juglans spp)	12-18
48	Watermelon (Citrullus vulgaris)	6

382. SOIL pH ADAPTATIONS: PLANTS

Plant growth is best at the pH indicated and only fair at the limits of the ranges shown in parentheses - estimates "c" of the 95% range (cf Introduction).

	Species	Soil pH
	Field and Forage Crops	
1	Alfalfa (Medicago sativa)	6.0-7.5(5.5-8.5)
2	Barley (Hordeum vulgare)	6.0-7.5(5.5-8.5)
3	Beet, sugar (Beta vulgaris)	6.5-8.0(5.5-8.5)
4	Bluegrass, Kentucky (Poa pratensis)	5.5-7.5
5	Buckwheat (Fagopyrum esculentum)	5.5-7.0(4.5-8.0)
6	Clover, red (Trifolium pratense)	6.0-7.5
7	Clover, white (T. repens)	6.0-7.5
8	Cotton (Gossypium hirsutum)	5.0-6.5(to 8.5)
9	Flax (Linum usitatissimum)	5.0-7.0(to 8.5)
10	Hemp (Cannabis sativa)	6.0-7.5
11	Oat (Avena sativa)	5.0-7.5(4.5-8.0)
12	Peanut (Arachis hypogaea)	5.0-6.5(to 8.0)
13	Redtop (Agrostis alba)	5.0-6.5
14	Rice (Oryza sativa)	5.0-6.5
15	Rye (Secale cereale)	5.0-7.0(4.5-8.0)
16	Sorghum (Sorghum vulgare)	5.5-7.5(5.5-8.0)
17	Soybean (Glycine soja)	6.0-7.5
18	Sugar cane (Saccharum officinarum)	6.0-8.0(5.0-)
19	Sunflower (Helianthus annuus)	6.0-7.5
20	Sweetclover (Melilotus alba)	6.5-8.0
21	Tobacco (Nicotiana tabacum)	5.5-7.5(4.5-)
22	Wheat (Triticum aestivum)	5.5-7.5(5.0-8.5)
	Fruit and Vegetable Crops	
23	Apple (Pyrus malus)	5.0-6.5(to 8.0)
24	Bean, lima (Phaseolus lunatus macrocarpus)	6.0-7.5
25	Bean, string (P. vulgaris)	6.0-7.5
26	Beet, garden (Beta vulgaris)	6.0-7.5
27	Blueberry (Vaccinium spp)	4.5-6.0
28	Cabbage (Brassica oleracea capitata)	6.0-7.5(to 8.5)
29	Cantaloupe (Cucumis melo)	6.0-8.0
30	Carrot (Daucus carota)	5.5-7.0(5.0-8.5)
31	Celery (Apium graveolens dulce)	6.0-7.5(to 8.5)
32	Corn (Zea mays)	5.5-7.5(5.0-8.0)
33	Cucumber (Cucumis sativus)	5.5-7.0(to 8.0)
34	Lemon (Citrus limonia)	6.0-7.5(to 8.5)
35	Lettuce (Lactuca sativa)	6.0-7.5(5.5-8.0)
36	Onion (Allium cepa)	6.0-7.5(5.0)
37	Orange, sweet (Citrus sinensis)	6.0-7.5
38	Parsley (Petroselimum hortense)	5.0-7.0
39	Pea, garden (Pisum sativum)	6.0-8.0
40	Peach (Prunus persica)	6.0-7.5
41	Pear (Pyrus communis)	6.0-7.5
42	Pepper (Capsicum annuum)	5.5-7.0
43	Pineapple (Ananas sativus)	5.0-6.5
44	Potato (Solanum tuberosum)	5.0-6.5(7.0-8.0)
45	Radish (Raphanus sativus)	5.5-7.0(5.0-8.0)
46	Spinach (Spinacia oleracea)	6.0-7.5(5.5-8.5)
47	Squash, winter (Cucurbita maxima)	5.5-7.0
48	Strawberry (Fragaria spp)	5.0-6.5(4.5-8.0)
49	Sweetpotato (Ipomoea batatas)	5.0-6.5(to 7.5)
50	Tomato (Lycopersicon esculentum)	5.5-7.5(4.5-)
51	Turnip (Brassica napus)	5.5-7.0
52	Watermelon (Citrullus vulgaris)	5.0-6.5(5.0-8.0)
	Ornamental Plants	
53	African-violet (Saintpaulia ionantha)	5.5-7.0
54	Almond, flowering (Prunus glandulosa)	6.0-7.5
55	Aster, China (Callistephus chinensis)	6.0-7.5(5.5-)
56	Balsam, garden (Impatiens balsamina)	6.0-7.5(5.5-)
57	Begonia (Begonia spp)	5.5-7.0
58	Boxwood (Buxus sempervirens)	6.0-7.5
59	Camellia (Camellia japonica)	4.5-6.0
60	Canna (Canna indica)	6.0-8.0
61	Carnation (Dianthus caryophyllus)	6.0-7.5(5.0-)
62	Chrysanthemum (Chrysanthemum morifolium)	6.0-7.5(5.0-8.0)
63	Coleus (Coleus blumei)	6.0-7.5
64	Dahlia (Dahlia spp)	6.0-8.0
65	Gardenia (Gardenia jasminoides)	5.0-6.0
66	Geranium (Pelargonium domesticum)	6.0-8.0(5.0-)
67	Gladiolus (Gladiolus spp)	6.0-8.0
68	Hibiscus, Chinese (Hibiscus rosa-sinensis)	6.0-8.0
69	Hyacinth (Hyacinthus orientalis)	6.0-7.5
70	Iris, bearded (Iris spp)	6.0-8.0
71	Ivy, English (Hedera helix)	6.0-8.0
72	Kalanchoe (Kalanchoe blossfeldiana)	6.0-7.5
73	Lily, Easter (Lilium longiflorum)	6.0-7.5
74	Nasturtium (Tropaeolum majus)	5.5-7.5
75	Narcissus (Narcissus spp)	5.0-7.0

	Species	Soil pH
	Ornamental Plants (concluded)	
76	Primrose, evening (Oenothera biennis)	6.0-8.0
77	Rose (Rosa hybrida)	5.5-7.0(5.0-7.5)
78	Snapdragon (Antirrhinum majus)	6.0-7.5(5.0-8.0)
79	Spiderwort (Tradescantia virginiana)	5.0-7.5
80	Stock (Matthiola incana)	6.0-7.5
81	Tulip (Tulipa gesneriana)	6.0-7.5
	Trees and Shrubs	
82	Acacia (Acacia spp)	6.5-8.0
83	Ailanthus (Ailanthus altissima)	6.0-8.0
84	Alder (Alnus spp)	6.0-7.5
85	Aspen, quaking (Populus tremuloides)	4.0-5.5
86	Baldcypress (Taxodium distichum)	6.0-7.5
87	Basswood (Tilia spp)	6.0-7.5
88	Beech, European (Fagus sylvatica)	6.0-7.5
89	Beech, American (F. grandifolia)	5.0-6.5
90	Birch, sweet (Betula lenta)	4.5-6.0
91	Buckeye, Ohio (Aesculus glabra)	6.0-7.5
92	Buckeye, red (A. pavia)	5.0-6.5
93	Catalpa (Catalpa spp)	6.0-7.5
94	Cherry, choke (Prunus virginiana)	6.0-7.5
95	Chestnut, American (Castanea dentata)	4.0-6.5
96	Chinkapin, Allegheny (C. pumila)	4.0-6.5
97	Dogwood, flowering (Cornus florida)	5.0-6.5
98	Douglas-fir (Pseudotsuga taxifolia)	5.0-6.5
99	Elm (Ulmus spp)[1]	6.0-8.0
100	Eucalyptus (Eucalyptus spp)	6.5-8.0
101	Fir (Abies spp)	4.0-6.5
102	Ginkgo (Ginkgo biloba)	5.5-7.0
103	Hackberry (Celtis spp)	6.0-7.5
104	Hemlock, eastern (Tsuga canadensis)	4.5-6.0
105	Hickory, shagbark (Carya ovata)	6.0-6.5
106	Holly, American (Ilex opaca)	4.5-6.0
107	Holly, English (I. aquifolium)	5.0-6.5
108	Honeylocust (Gleditsia triacanthos)	6.0-7.5
109	Hophornbeam, eastern (Ostrya virginiana)	6.0-7.0
110	Hornbeam (Carpinus spp)	6.0-7.5
111	Horsechestnut (Aesculus hippocastanum)	5.5-7.0
112	Juniper (Juniperus spp)	5.5-7.5
113	Juniper, common (J. communis)	5.0-6.5
114	Juniper, mountain (J. communis saxatilis)	4.0-5.5
115	Coffeetree, Kentucky (Gymnocladus dioica)	6.0-7.5
116	Larch (Larix spp)	4.5-7.5
117	Locust (Robinia spp)	5.5-7.5
118	Magnolia, southern (Magnolia grandiflora)	5.0-7.0
119	Maple (Acer spp)	5.5-7.5
120	Maple, mountain (A. spicatum)	4.5-6.0
121	Mountain-ash, American (Sorbus americana)	4.5-6.5
122	Mountain-ash, European (S. aucuparia)	5.5-7.5
123	Mountain-laurel (Kalmia latifolia)	4.0-6.0
124	Mulberry (Morus spp)	6.0-7.5
125	Oak (Quercus spp)[2]	4.5-6.5
126	Oak (Quercus spp)[3]	4.0-5.0
127	Oak, English (Q. robur)	6.0-7.5
128	Oak, white (Q. alba)	5.5-7.5
129	Oak, willow (Q. phellos)	4.5-6.5
130	Paulownia, royal (Paulownia tomentosa)	5.5-7.5
131	Pine (Pinus spp)	4.0-6.5
132	Pine, longleaf (P. palustris)	4.0-6.0
133	Pine, red (P. resinosa)	5.0-6.0
134	Poplar (Populus spp)	5.5-7.5
135	Redbud, eastern (Cercis canadensis)	6.0-7.5
136	Redcedar, eastern (Juniperus virginiana)	5.0-8.0
137	Rhododendron (Rhododendron spp)	4.0-6.0
138	Service berry (Amelanchier spp)	5.0-7.5
139	Spruce (Picea spp)	4.0-6.5
140	Spruce, blue (P. pungens)	5.0-6.5
141	Spruce, Sitka (P. sitchensis)	5.0-6.5
142	Sweetgum (Liquidambar styraciflua)	5.0-6.5
143	Sycamore (Platanus spp)	5.5-7.5
144	Tupelo, black (Nyssa sylvatica)	4.5-6.0
145	Walnut (Juglans spp)	6.0-7.5
146	White-cedar, Atlantic (Chamaecyparis thyoides)	4.0-6.0
147	White-cedar, northern (Thuja occidentalis)	6.0-7.5(5.5-8.5)
148	Willow (Salix spp)	5.5-7.5
149	Willow, creeping (S. repens)	4.5-6.0
150	Yellow-poplar (Liriodendron tulipifera)	5.5-7.5
151	Yew (Taxus spp)	5.0-7.5

/1/ Species include: American elm (U. americana), Chinese elm (U. parvifolia). /2/ Species include: black oak (Q. velutina), northern red oak (Q. rubra), scarlet oak (Q. coccinea). /3/ Species include: blackjack oak (Q. marilandica), post oak (Q. stellata), turkey oak (Q. laevis), southern red oak (Q. falcata). For pin oak (Q. palustris) and chestnut oak (Q. prinus), 6.0-7.0.

383. BORON TOLERANCE: PLANTS

For each tolerance group, plants are listed in order of decreasing tolerance to boron present in nutrient solutions. Differences of a few places in position may not be significant, and there is no sharp division between successive groups. Boron concentrations indicate the range within which injury was observed at the time of harvest.

	High Tolerance (Boron 25-10 ppm)
1	Athel (Tamarix aphylla)
2	Asparagus (Asparagus officinalis)
3	Palm (Phoenix canariensis)
4	Date (P. dactylifera)
5	Beet, sugar (Beta vulgaris)
6	Beet, mangel (B. vulgaris)
7	Beet, garden (B. vulgaris)
8	Alfalfa (Medicago sativa)
9	Gladiolus (Gladiolus spp)
10	Broadbean (Vicia faba)
11	Onion (Allium cepa)
12	Turnip (Brassica rapa)
13	Cabbage (B. oleracene cap.)
14	Lettuce (Lactuca sativa)
15	Carrot (Daucus carota)
	Medium Tolerance (Boron 10-5 ppm)
16	Sunflower (Helianthus annuus)
17	Potato (Solanum tuberosum)

	Median Tolerance (Boron 10-5 ppm) (concluded)
18	Cotton, Acala (Gossypium hirsutum)
19	Cotton, Pima (G. barbadense)
20	Tomato (Lycopersicon esculentum)
21	Sweet pea (Lathyrus odoratus)
22	Radish (Raphanus sativus
23	Pea, field (Pisum sp)
24	Olive (Olea europaea)
25	Barley (Hordeum vulgare)
26	Wheat (Triticum aestivum)
27	Corn (Zea mays)
28	Milo (Sorghum vulgare)
29	Oat (Avena sativa)
30	Zinnia (Zinnia sp)
31	Pumpkin (Cucurbita pepo)
32	Pepper, bell (Capsicum sp)
33	Sweetpotato (Ipomoea batatas)
34	Bean (Phaseolus lunatus mac.)
	Low Tolerance (5-1 ppm)
35	Pecan (Carya illinoensis)

	Low Tolerance (5-1 ppm) (concluded)
36	Walnut (Jugians nigra)
37	Walnut (J. regia)
38	Artichoke (Helianthus tuberosus)
39	Bean, navy (Phaseolus vulgaris)
40	Elm (Ulmus americana)
41	Plum (Prunus sp)
42	Pear (Pyrus communis)
43	Apple (P. malus)
44	Grape, Malaga and Sultanina (Vitis viniferx)
45	Fig, Kadota (Ficus carica)
46	Persimmon (Diospyros virginiana)
47	Cherry (Prunus spp)
48	Peach (P. persica)
49	Apricot (P. armeniaca)
50	Blackberry, thornless (Rubus sp)
51	Orange (Citrus spp)
52	Avocado (Persea gratissima)
53	Grapefruit (Citrus paradisi)
54	Lemon (C. limonia)

384. SALT TOLERANCE: PLANTS

Salinity values are expressed in terms of electrical conductivity (EC_e) of the saturation extract of active root-zone soil, and are for total soluble salts. Units of conductivity measurement are millimhos per cm at 25°C. In each tolerance group, plants are listed in order of decreasing salt tolerance; however, individual differences from one place to the next may not be significant.

Part I: EFFECT ON CROP YIELD

Data correlate soil salinity with crop yield. Plants listed at the beginning and at the end of each tolerance group may be expected to produce only 50% of a normal yield when grown in soils of salinity represented in upper and lower ranges.

	Fruit Crops
	High Tolerance
1	Date (Phoenix dactylifera)
	Medium Tolerance
2	Pomegranate (Punica granatum)
3	Fig (Ficus carica)
4	Olive (Olea europaea)
5	Grape (Vitis vinifera)
6	Cantaloupe (Cucumis melo canta.)
	Low Tolerance
7	Pear (Pyrus communis)
8	Apple (P. malus)
9	Prune (Prunus sp)
10	Plum (P. americana)
11	Almond (Amygdalus communis)
12	Apricot (Prunus armeniaca)
13	Peach (P. persica)
14	Strawberry (Fragaria sp)
	Vegetable Crops
	High Tolerance (EC_e x1000=12-10)
15	Beet, garden (Beta vulgaris)
16	Kale (Brassica oleracea acephala)
17	Asparagus (Asparagus officinalis)
18	Spinach (Spinacia oleracea)
	Medium Tolerance (EC_e x1000=10-4)
19	Tomato (Lycopersicon esculentum)
20	Broccoli (Brassica oleracea italica)
21	Cabbage (B. oleracea capitata)
22	Pepper, bell (Capsicum sp)
23	Cauliflower (Brassica oleracea bot.)
24	Lettuce (Lactuca sativa)
25	Corn, sweet (Zea mays)
26	Potato (Solanum tuberosum)
27	Carrot (Daucus carota)
28	Onion (Allium cepa)
29	Pea (Pisum sativum)

	Vegetable Crops (concluded)
	Medium Tolerance (EC_e x 1000 = 10-4) (concl'd)
30	Squash (Cucurbita spp)
31	Cucumber (Cucumis sativus)
	Low Tolerance (EC_e x1000=4-3)
32	Radish (Raphanus sativus)
33	Celery (Apium graveolens)
34	Bean, garden (Phaseolus vulgaris)
	Field Crops
	High Tolerance (EC_e x1000=16-10)
35	Barley (Hordeum vulgare)[1]
36	Beet, sugar (Beta vulgaris)
37	Rape (Brassica napus)
38	Cotton (Gossypium sp)
	Medium Tolerance (EC_e x1000=10-6)
39	Rye (Secale cereale)[1]
40	Wheat (Triticum aestivum)[1]
41	Oat (Avena sativa)[1]
42	Rice (Oryza sativa)
43	Sorghum (Sorghum vulgare)[1]
44	Corn (Zea mays)
45	Flax (Linum usitatissimum)
46	Sunflower (Helianthus annuus)
47	Castor bean (Ricinus communis)
	Low Tolerance (EC_e x1000-4)
48	Bean, field (Phaseolus sp)
	Forage Crops
	High Tolerance (EC_e x 1000 = 18-12)
49	Saccaton (Sporobolus airoides)
50	Saltgrass (Distichlis stricta)
51	Nuttall alkali grass (Puccinellia nuttelliana)
52	Bermuda grass (Cynodon dactylon)
53	Rhodes grass (Chloris gayana)
54	Rescue grass (Bromus catharticus)
55	Wild rye (Elymus canadensis)
56	Wild rye (E. triticoides)

	Forage Crops (concluded)
	High Tolerance (EC_e x 1000 = 18-12) (concluded)
57	Wheatgrass (Agropyron smithii)
58	Barley (Hordeum vulgare)[2]
59	Trefoil (Lotus corniculatus)
	Medium Tolerance (EC_e x1000=12-4)
60	Sweetclover (Melilotus alba)
61	Sweetclover (M. officinalis)
62	Ryegrass (Lolium perenne)
63	Brome (Bromus marginatus)
64	Clover (Trifolium fragiferum)
65	Dallis grass (Paspalum dilatatum)
66	Sudan grass (Sorghum sudanense)
67	Sweetclover, hubam (Melilotus alba)
68	Alfalfa (Medicago sativa)
69	Fescue (Festuca elatior arundinacea)
70	Rye (Secale cereale)[2]
71	Wheat (Triticum aestivum)[2]
72	Oat (Avena sativa)[2]
73	Orchard grass (Dactylis glomerata)
74	Bluegrama (Bouteloua gracilis)
75	Fescue (Festuca elatior)
76	Canary grass (Phalaris arundinacea)
77	Trefoil (Lotus uliginosus)
78	Brome (Bromus inermis)
79	Oatgrass (Arrhenatherum elatius)
80	Milk vetch (Astragalus cicer)
81	Sourclover (Melilotus indica)
82	Milk vetch (Astragalus falcatus)
	Low Tolerance (EC_e x1000=4-2)
83	Whitetclover (Trifolium repens)
84	Foxtail (Alopecurus pratensis)
85	Clover (Trifolium hybridum)
86	Clover (T. pratense)
87	Clover, Ladino (T. repens)
88	Burnet (Sanguisorba minor)

[1] Tolerance determined on basis of yield of grain. [2] Determined as yield in hay.

Part II: EFFECT ON PLANT

Data are based on soil salinity values at which no evidence of toxicity is generally observed. For citrus and avocados the salts present in the soil were predominantly chlorides; for other plants, a mixture of chlorides and sulfates.

	Medium Tolerance (EC_e x1000=8-4)
	Grapefruit (Citrus paradisi)
1	on Rangpur lime
	Orange (Citrus spp)
2	on Cleopatra mandarin
	Grapefruit (C. paradisi)
3	on Cleopatra mandarin
4	on Tunkat mandarin
	Poor Tolerance (EC_e x1000=4-2)
	Orange (Citrus spp)
5	on sour lime
	Grapefruit (C. paradisi)
6	on rough lemon
7	on sour orange

	Poor Tolerance (EC_e x 1000 = 4-2) (concluded)
	Grapefruit (Citrus paradisi) (concluded)
8	on Sampson tangelo
9	on sweet orange
	Lemon (C. limonia)
10	on sour orange
11	Plum, Natal (Prunus americana)
	Avocado, West Indian (Persea gratissima)
12	on West Indian
13	Cherry, Surinam (Prunus sp)
14	Cherry, haden (Prunus sp)
	Very Poor Tolerance (EC_e x1000=2-1)
15	Papaya (Carya papaya)
	Avocado, Lula (Persea gratissima)
16	on West Indian

	Very Poor Tolerance (EC_e x 1000 = 2-1) (concluded)
	Avocado, Mexican
17	on West Indian
	Grapefruit (Citrus Paradisi)
18	on trifoliate-orange
19	on Troyer citrange
20	on Kara mandarin
21	on king orange
22	Sapote, white
23	Mango, Saigon (Mangifera indica)
24	Mango, Brooks (M. indica)
	Avocado, Mexican (Persea gratissima)
25	on Mexican
26	Cherimoya (Annona cherimola)

385. SALINITY TOLERANCES: AQUATIC ANIMALS

Data are based on field observations unless otherwise indicated in footnotes. Tolerance to salinity alone is often not the most critical factor, as it differs with the age of the individual, temperature and hydrogen ion concentration of the water, previous conditioning, length of exposure, and other variables. Values represent lower and upper limits of salinity at which these animals have been found to survive. Salinity is defined as the total weight of dissolved solids in 1 kg of water at 27°C (80.6°F), expressed as g/kg or o/oo.

FW = fresh water; BW = brackish water; MW = marine water; SLW = highly saline lake water.

	Animal	Normal Habitat[1]	Salinity Tolerance g/kg or o/oo
	Porifera		
1	Sponge, boring or sulfur (Cliona celata)	MW	15-36
	Coelenterata		
2	Hydra (Chlorohydra and Pelmatohydra)	FW	0-2.5
3	Hydroid (Clava)	BW	10-30
4	Moon jelly (Aurelia aurita)	MW	16-35
5	Sea nettle (Dactylometra quinquecirrha)	MW	16-35
6	Sea panay (Renilla mueller)	MW	27-37
	Turbellaria		
7	Flatworm (Procerodes littoralis)	BW	3.5-35[2]
	Annelida		
8	Clamworm (Nereis diversicolor)	BW	4-32[3]
	Mollusca		
9	Octopus (Octopus vulgaris)	MW	30-35
10	Oyster, eastern (Crassostrea virginica)	MW, BW	7-27[4]
11	Oyster, horse (Ostrea equestris)	MW	27-35
12	Squid, common (Loligo pealii)	MW	31-36
13	Squid, short (Lolliguncula brevis)	MW	16-37
14	Tun, giant (Tonna galea)	MW	30-38
15	Whelk, lightning (Busycon contrarium)	MW	20-37
	Crustacea		
16	Crab (Heloecius cordiformis)	BW, MW	0.7-53
17	Crab, blue (Callinectes sapidus)[5]	BW, MW	0-37
18	Crab, gulf (C. danae)	MW	17-37
19	Crab, mitten (Eriocheir sinensis)[6]	FW, BW, MW	0-47
20	Crab, stone (Menippe mercenaria)[7]	BW, MW	12-34
21	Sea bob (Xiphopenaeus kryeri)	MW	22-36
22	Shrimp (Crago franciscorum)	MW	12-35
23	Shrimp (Palaemon longirostris)	MW	0-35
24	Shrimp, brine (Artemia salina)	SLW	<35-220[8]
25	Shrimp, grass (Palaemonetes vulgaris)[9]	BW, MW	2-34
26	Shrimp, white (Penaeus setiferus)[10]	BW, MW	0.8-35
	Echinodermata		
27	Sand dollar (Mellita quinquiesperforata)	MW	30-35
28	Star, brittle or serpent (Amphiodia limbata)[11]	BW, MW	8.9-36
	Elasmobranchii[12]		
29	Sawfish, Pacific (Pristis microdon)	MW[13]	0-35
30	Shark, blacknose (Carcharhinus limbatus)	MW	11-35
31	Shark, bonnethead (Sphyrna tiburo)	MW	23-36
32	Shark, Ganges (Carcharhinus gangeticus)	MW[13]	0-35
33	Stingray (Dasyatis americana)	MW	29-36
34	Stingray (D. sabina)	MW[13]	0-37
35	Torpedo fish (Narcine brasiliensis)	MW	31-37
	Teleostomi[14]		
36	Anchovy (Anchoa hepsetus)	BW	2.5-37
37	Anchovy, bay (A. mitchilli diaphana)	BW[13]	0-37
38	Archerfish (Toxotes jaculator)	MW, BW, FW	0-35
39	Bararog (Leiognathus caballus)	MW	0-35
40	Barb (Puntius javanicus)	FW	0-8
41	Bass, mountain (Kuhlia sandvichenis)	MW, BW[13]	0-35
42	Batfish, silver (Monodactylus argenteus)	MW, BW	0-35
43	Blowfish (Sphoeroides marmoratus)	MW	4.4-36
44	Bumper (Chlorosocombrus chrysurus)	MW	17-37
45	Carp (Cyprinus carpio)	FW	0-10
46	Catfish, blue (Ictalurus furcatus)	FW	0-6.9
47	Catfish, sea (Galeichthys felis)	MW, BW[13]	0-60
48	Croaker (Micropogon undulatus)	MW, BW	0-37
49	Croaker, spot (Leiostomus xanthurus)	MW, BW[13]	0-37
50	Cutlassfish (Trichiurus lepturus)	MW	13-37
51	Damselfish (Pomacentrus fuscus)	MW	0-35
52	Drum, black (Pogonias cromis)	MW, BW	0-50
53	Drum, channel (Sciaenops ocellata)	MW, BW	0-32
54	Drum, star (Stellifer lanceolatus)	MW	8.9-37
55	Eel, European (Anguilla vulgaris)	FW, MW	0-35
56	Fagulo (Limia vittata)	FW, BW	0-35
57	Flounder, European (Pleuronectes flesus)	MW	7-35

	Animal	Normal Habitat[1]	Salinity Tolerance g/kg or o/oo
	Teleostomi (concluded)		
58	Flounder, fringed (Etropus crossotus)	MW	4.4-37
59	Flounder, gulf (Paralichthys lethostigma)	MW, BW[13]	0-36
60	Flounder, Gunter's (Syacium gunteri)	MW	31-35
61	Gaff-topsail (Bagre marina)	MW, BW[13]	0-34
62	Gar, alligator (Lepisosteus spatula)	BW	0-31
63	Goby, darting (Gobionellus boleosoma)	MW	15-30
64	Goby, naked (Gobiosoma bosci)[13]	BW	0-20
65	Goldfish (Carassius auratus)	FW	0-15
66	Green chromide (Etroplus suratensis)	BW	0-35
67	Grouper, high-finned (Cromileptes altivelis)	MW[13]	0-35
68	Hake, southern (Urophycis floridanus)	MW	13-34
69	Jack (Caranx ignobilis)	MW[13]	0-35
70	Jack (C. exafasciatus)	MW[13]	0-35
71	Jack, common (C. hippos)	MW[13]	0-36
72	Jarbua (Therapon jarbua)	MW, BW	0-35
73	Killifish, California (Fundulus parvipinnis)	MW[15]	0-35[16]
74	Killifish, gulf (F. grandis and F. similis)	MW[17]	2-37[16]
75	Killifish, mummichog (F. heteroclitus)	MW[17]	0-35[16]
76	Langaray (Ambassis lala)	MW, BW, FW	0-35
77	Menhaden (Brevoortia smithi)	BW	2-34
78	Milkfish (Chanos chanos)	MW	0-35
79	Minnow, variegated (Cyprinodon variegatus)	BW[13]	0-71
80	Mojarra (Eucinostomus argenteus)	MW[13]	0-37
81	Moonfish (Vomer setapinnis)	MW	17-37
82	Mouthbreeder (Tilapia mossambica)	FW[18]	0-69
83	Mudskipper (Periophthalmus barbarus)	BW	0-35
84	Mullet, striped (Mugil cephalus)	MW, BW[13]	0-35[16]
85	Needlefish (Strongylura marina)	MW, BW[13]	0-37
86	Paradise fish (Macropodus opercularis)	FW	0-30
87	Pigfish (Orthopristis chrysoptera)	MW	10-37
88	Pinfish (Lagodon rhomboides)	MW, BW[13]	0-37
89	Pipefish (Syngnathus scovelli)	MW	0-26
90	Pompano, common (Trachinotus carolinus)	MW	28-37
91	Rain-water fish (Lucania parva vemusta)	BW[13]	0-24
92	Sailfin molly (Mollienesia latipinna)	FW, BW[13]	0-87
93	Salmon, chum (Oncorhynchus keta), fry	FW	0-30
94	Salmon, king (O. tshawytscha)	FW, MW	0-35
95	Salmon, silver (O. kisutch), fry	FW	0-15
96	Sardine, silver (Harengula pensacolae)	BW	4.8-37
97	Scaifish (Scatophagus argus)	MW, BW, FW	0-35
98	Scatfish (Selenotoca papuensis)	MW, BW	0-35
99	Sea perch, silver (Lates calcarifer)	MW	0-35
100	Sea robin (Prionotus tribulus)	MW	10-37
101	Shad, gizzard (Dorosoma cepedianum)	BW	0-34
102	Sheepshead (Archosargus probatocephalus)	BW	2.2-30
103	Silverside, common (Menidia beryllina)	BW[13]	0 to >80
104	Sleeper, striped (Dormitator maculatus)	BW[13]	0-35
105	Snapper (Lutianus argentiventris)	MW[13]	0-35
106	Sole, broad (Trinectes fasciatus)	MW, BW[13]	0-34
107	Sole, lined (Achirus lineatus)	MW	2.5-36
108	Spadefish (Chaetodipterus faber)	MW	11-36
109	Squeteague, sand (Cynoscion arenarius)	BW	4.9-30
110	Squeteague, sand (C. nothus)	MW	18-37
111	Squeteague, spckled (C. nebulosus)	BW[13]	0-75
112	Stickleback, 3-spine (Gasterosteus aculeatus)	FW, MW	0-55
113	Tarpon (Tarpon atlanticus)	MW[13]	0-35
114	Tarpon, Asiatic (Megalops cyprinoides)	MW[13]	0-35
115	Tenpounder (Elops saurus)	MW, BW[13]	0-35
116	Threadfin (Polydactylus octonemus)	BW	2.1-37
117	Tonguefish (Symphurus plagiusa)	MW	17-37
118	Trout, steelhead (Salmo gairdneri)	FW, MW	0-35
119	Whiff (Citharichthys spilopterus)	BW[13]	0-36.7
120	Whiting (Menticirrhus americanus)	MW	14-37
121	Whiting, surf (M. littoralis)	MW	18-37
122	Yellowtail (Hairdiella chrysurus)	BW	2.1-34

/1/ Brackish water species are usually euryhaline, i.e., able to live in waters of a wide range of salinity. Calcium ions aid fishes to withstand low salinities; field observations indicate that all marine animals invade fresh water of high Ca concentration much more than they do Ca-deficient fresh waters. /2/ Can undergo these changes with the tidal cycle. /3/ Has been adapted to chlorinities of about 0.25, and also observed in nearly fresh water in Denmark. /4/ Oysters withstand short-time salinity changes of 0-42 in the laboratory. /5/ May live in fresh water, but normal habitat is in estuarine waters of high salinity. /6/ Normally lives in fresh or brackish water, migrating to sea only to release larvae. /7/ Probably occurs more commonly in marine than brackish water. /8/ Occurs only in highly saline lakes; will tolerate sea water of <35 salinity (laboratory), but is not found in sea water of this salinity or other waters where there are predatory fish (Laguna Madre, Sues Canal). /9/ Recently split into 3 spp: P. vulgaris, P. intermedius, and P. pugio; it is possible that P. vulgaris does not occur in waters of low salinity. /10/ Only immature stages occur in brackish water. /11/ The common sea star (Asterias forbesi) can tolerate salinities down to 16 for short periods, and 18 regularly; A. rubens of Europe lives in a salinity of 18. /12/ Field observations; listed species where discovered in waters of known salinities; this constitutes a measure of tolerance, but does not indicate what are the physiological limits of tolerance to changes in salinity. /13/ Migrates into fresh water. /14/ Many marine teleosts can tolerate reduced salinity or fresh water if the change is not sudden. /15/ Abrupt transfer to fresh water causes 5-80% mortality. /16/ Salinity tolerance of 80-100 also reported. /17/ Gradual transfer to fresh water causes 11.5-56% mortality; abrupt transfer to fresh water causes 100% mortality. /18/ Will spawn in both fresh and salt water.

386. pH RANGE FOR GROWTH: REPRESENTATIVE MICROORGANISMS

	Organism	Medium[1]	Temp °C	pH			Organism	Medium[1]	Temp °C	pH	
				Optimum	Range					Optimum	Range
1	Bacteria			6.5-7.5	3.8-12.0	20	Colpoda cucullus			6.5; 7.5	5.5-9.5
2	Molds			4.0-5.8	1.5-8.5	21	Didinium sp	S		6.4-8.4	5.2-9.4
3	Yeasts			3.8-6.0	2.5-8.0	22	Gastrostyla sp				6.0-8.5
	Protozoa[2]					23	Glaucoma scintillans	B		5.6-6.8	
	Flagellates					24	Holophrya sp				6.5-7.4
4	Astasia klebsii	P	25	4.2-6.0	3.2-8.2	25	Paramecium aurelia	HF	25	7.0	5.7-7.8
5	A. longa	TR	25	6.0	3.3-9.6	26	P. bursaria	MS + P	19-26	6.7-6.8	4.9-8.0
6	Chilomonas paramecium	P	28	4.8-5.1	4.1-8.4	27	P. caudatum	L		7.1-7.4	6.5-7.8
7	Chlorogonium elongatum	P	28	7.8	4.9-8.7	28	P. caudatum	HT	24	6.9-7.1	6.0-9.5
8	C. euchlorum	P	28	7.4	4.8-8.7	29	P. multimicronucleatum	HT	27	7.0	4.8-8.3
9	C. tetragonium	T + MS	28	8.6	4.2-8.8	30	P. polycaryum	LT		6.9-7.3	5.0-7.5
10	Euglena anabaena	P	29,5	6.9	4.5-8.3	31	P. trichium	HT		6.7-7.1	6.2-7.1
11	E. deses	P	29,5	7.0	5.3-8.0	32	P. woodruffi	L		7.0-7.5	6.5-7.5
12	E. gracilis	P	28,3	6.6	3.9-9.9	33	Plagiopyia sp				6.9-7.5
13	E. klebsii	P		6.5	5.5-7.5	34	Sprostomum ambiguum			7.4	6.8-7.5
14	E. mutabilis	P		3.4-5.4	2.1-7.7	35	Stentor coeruleus	MP	18-20	7.7-8.0	
15	E. pisciformis	P			6.0-8.0	36	Stylonychia pustuinta	HT	25	6.7; 8.0	6.0-8.0
16	E. stellata	P		5.5	4.5-8.0	37	Tetrahymena pyriformis E	T	25	5.5; 7.4	4.5-8.5
17	E. viridis	MS			4.0-7.2	38	T. pyriformis GF-J	T	28	5.1-6.0	4.9-9.5
18	Poiytomella caeca	P			2.2-9.2	39	T. pyriformis GL	T	28	4.8-5.3	4.0-8.9
	Ciliates					40	T. pyriformis T-P	PH	24	7.0; 9.0	
19	Amphileptus sp			7.1-7.3		41	T. vorax D	P		6.2-7.6	

[1] A = acetate; B = brewers yeast-Harris; HF = hay + flour; HT = hay tea; L = lettuce-sea water; LT = lettuce tea; MP = modified peters + ciliates; MS = mineral salts; P = peptone; PH = pheips; S = spring water + paramecium; T = tryptone; TR = tryptophan. [2] Exclusive of all parasitic forms.

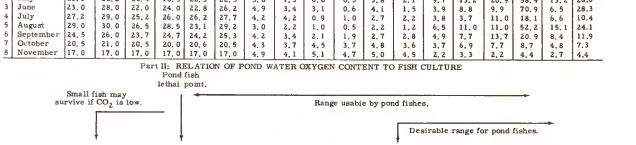
387. FACTORS AFFECTING POND FISH CULTURE

Part I: TEMPERATURE, DISSOLVED OXYGEN AND CARBON DIOXIDE: FERTILIZED AND UNFERTILIZED PONDS (SOUTHERN U.S.A)

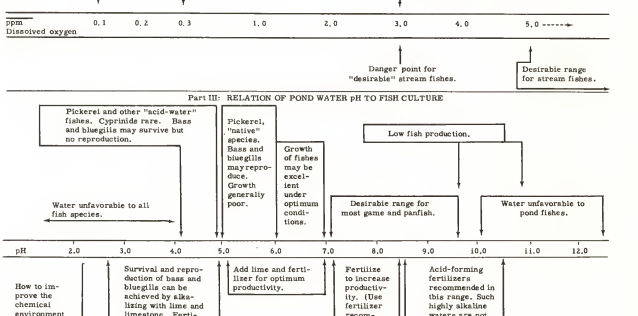
F = fertilized pond, area 1.3 acres, maximum depth 9 ft, bottom sample taken at 5 ft., 11 applications of 100 lb of 8-8-2 (N-K-P) per acre; U = unfertilized pond, 1.8 acres, maximum depth 9 ft, bottom sample taken at 7.5 ft. Averages are from 4 depths.

Month		Temperature, °C						Oxygen, ppm						Carbon Dioxide, ppm					
		Surface		Bottom		Average		Surface		Bottom		Average		Surface		Bottom		Average	
		U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
1	April	21.0	23.5	17.0	15.5	18.9	19.0	4.1	9.0	1.9	1.3	4.3	4.4	3.3	2.2	4.4	3.3	4.7	3.0
2	May	23.8	26.2	20.5	18.5	22.3	22.5	5.6	7.5	0.6	0.5	3.8	2.1	9.7	13.2	20.9	58.4	13.2	28.0
3	June	23.0	28.0	22.0	24.0	22.8	26.2	4.9	3.4	3.1	0.6	4.1	1.5	3.9	8.8	9.9	70.9	6.5	28.3
4	July	27.2	29.0	25.2	26.0	26.2	27.7	4.2	4.2	0.9	1.0	2.7	2.2	3.8	3.7	11.0	18.1	6.6	10.4
5	August	29.0	30.0	26.5	28.5	23.1	29.2	3.0	2.2	1.0	0.5	2.2	1.2	6.5	11.0	11.0	52.2	15.1	24.1
6	September	24.5	26.0	23.7	24.7	24.2	25.3	4.2	3.4	2.1	1.9	2.7	2.8	4.9	7.7	13.7	20.9	8.4	11.9
7	October	20.5	21.0	20.5	20.0	20.6	20.5	4.3	3.7	4.5	3.7	4.8	3.6	3.7	6.9	7.7	8.7	4.8	7.3
8	November	17.0	17.0	17.0	17.0	17.0	17.0	4.9	4.1	5.1	4.7	5.0	4.5	2.2	3.3	2.2	4.4	2.7	4.4

Part II: RELATION OF POND WATER OXYGEN CONTENT TO FISH CULTURE



Part III: RELATION OF POND WATER pH TO FISH CULTURE



388. SHADE TOLERANCE: SHRUBS AND HERBACEOUS PLANTS

T = highly tolerant; t = moderately tolerant; I = intermediate; f = moderately intolerant; T = highly intolerant.

	Species	Toler-ance
	Shrubs	
1	Abelia (Abelia grandiflora)	I
2	Barberry (Berberis thunbergi)	f
3	Beauty bush (Kolkwitzia amabilis)	I
4	Blueberry (Vaccinium corymbosum)	T
5	Boxwood (Buxus microphylla)	I
6	Buckthorn (Rhamnus cathartica)	t
7	Burningbush (Evonymus atropurpurea)	I
8	Chokeberry (Aronia atropurpurea)	f
9	Coralberry (Symphoricarpos orbiculatus)	I
10	Cranberry (Viburnum opulus)	T
11	Currant (Ribes americanum)	T
12	Dogwood (Cornus racemosa)	I
13	Dogwood (C. stolonifera)	f
14	Elderberry (Sambucus canadensis)	I
15	Elderberry (S. racemosa)	t
16	Firethorn (Pyracantha coccinea)	t
17	Forsythia (Forsythia suspensa)	I
18	Gooseberry (Ribes cynosbati)	T
19	Holly, Japanese (Ilex crenata)	t
20	Honeysuckle (Lonicera japonica)	t
21	Honeysuckle (L. sempervirens)	f
22	Honeysuckle (L. tatarica)	I
23	Laurel (Kalmia latifolia)	f
24	Lilac (Syringa vulgaris)	I
25	Mahonia (Mahonia aquifolium)	t
26	Maple (Acer pennsylvanicum)	T
27	Mockorange (Philadelphus coronarius)	I
28	Peashrub (Caragana arborescens)	I
29	Photinia (Photinia villosa)	t
30	Prickly-ash (Zanthoxylum americanum)	T
31	Privet (Ligustrum amurense)	t
32	Rhododendron (Rhododendron spp)	T
33	Spice bush (Lindera benzoin)	t
34	Viburnum (Viburnum acerifolium)	T
35	Viburnum (V. dentatum)	t
36	Winterberry (Ilex verticillata)	t
37	Witch hazel (Hamamelis mollis)	t
38	Yew (Taxus canadensis)	T

	Species	Toler-ance
	Herbaceous Flowers	
39	Ageratum (Ageratum spp)	I
40	Alyssum (Alyssum spp)	I
41	Anemone (Anemone quinquefolia)	t
42	Arbutus (Epigaea repens)	t
43	Aster (Aster spp)	I
44	Baneberry (Actaea spp)	t
45	Blood root (Sanguinaria canadensis)	t
46	Blue bead (Clintonia borealis)	T
47	Bluebell (Polemonium reptans)	t
48	Calendula (Calendula spp)	I
49	Cardinal flower (Lobelia cardinalis)	I
50	Chrysanthemum (Chrysanthemum spp)	I
51	Columbine (Aquilegia canadensis)	I
52	Cone-flower (Rudbeckia triloba)	t
53	Coral bells (Heuchera sanguinea)	I
54	Coral root (Corallorhiza maculata)	T
55	Cowslip (Mertensia virginica)	I
56	Day lily (Hemerocallis spp)	f
57	Foxglove (Digitalis purpurea)	t
58	Goldthread (Coptis trifolia)	T
59	Grape-hyacinth (Muscari azureum)	I
60	Hepatica (Hepatica triloba)	t
61	Iris (Iris cristata and verna)	I
62	Jack-in-the-pulpit (Arisaema triphyllum)	T
63	Lady's slipper (Cypripedium hirsutum)	t
64	Lady's slipper (C. pubescens)	t
65	Lily (Lilium spp)	f
66	Monkshood (Aconitum fisheri)	t
67	Narcissus (Narcissus spp)	I
68	Oxalis (Oxalis corniculata)	T
69	Oxalis (O. violacea)	t
70	Periwinkle (Vinca minor)	t
71	Petunia (Petunia hybrida)	f
72	Phlox (Phlox divaricata)	T
73	Phlox (P. paniculata)	t
74	Phlox (P. paniculata)	I
75	Plantain lily (Hosta spp)	T
76	Primrose (Primula vulgaris)	I

	Species	Toler-ance
	Herbaceous Flowers (concluded)	
77	Spiderwort (Tradescantia virginiana)	T
78	Squill (Scilla siberica)	T
79	Trillium (Trillium grandiflorum)	t
80	Trillium (T. undulatum)	T
81	Twin flower (Linnaea borealis)	T
82	Violet (Viola papilionacea)	T
83	Zinnia (Zinnia spp)	I
	Grasses	
84	Bluegrass (Bouteloua gracilis)	f
85	Bluegrass (Poa trivialis)	t
86	Fescue (Festuca rubra)	t
87	Wheatgrass (Agropyrum cristatum)	I
	Vegetable Crops	
88	Beet (Beta vulgaris)	I
89	Cauliflower (Brassica oleracea botrytis)	T
90	Celery (Apium graveolens dulce)	I
91	Eggplant (Solanum melongena esculentum)	I
92	Lettuce (Lactuca sativa)	f
93	Tomato (Lycopersicon esculentum)	I
	Pteridophytes - Ferns	
94	Beech (Phegopteris polypodioides)	T
95	Bladder (Cystopteris bulbifera)	t
96	Brake (Pteridium aquilinum)	t
97	Christmas (Polystichum acrostichoides)	T
98	Cinnamon (Osmunda cinnamomea)	t
99	Hartford (Lygodium palmatum)	t
100	Haysscented (Dennstaedtia punctilobula)	t
101	Interrupted (Osmunda claytoniana)	t
102	Lady (Asplenium filix-foemina)	T
103	Maidenhair (Adiantum pedatum)	T
104	Ostrich (Pteris pennsylvanica)	T
105	Polypody (Polypodium virginianum)	T
106	Walking (Camptosorus rhizophyllus)	T
107	Wood (Dryopteris marginalis)	t
	Pteridophytes - Fern Allies	
108	Clubmoss (Lycopodium lucidulum)	T
109	Horsetail (Equisetum hyemale)	T

389. SHADE TOLERANCE: FOREST TREES

T = highly tolerant; t = moderately tolerant; I = intermediate; f = moderately intolerant; T = highly intolerant.

	Species	Toler-ance
	Broadleaf Trees	
1	Ash (Fraxinus spp)[1]	t
2	Aspen (Populus spp)[2]	T
3	Basswood (Tilia spp)	T
4	Beech (Fagus grandifolia)	T
5	Birch (Betula lenta)	I
6	Birch (B. lutea)	I
7	Birch (B. papyrifera)	I
8	Birch (B. pendula)	T
9	Buckeye (Aesculus spp)	t
10	Butternut (Juglans cinerea)	f
11	Catalpa (Catalpa bignioides)	f
12	Cherry (Prunus serotina)	f
13	Chestnut (Castanea dentata)	I
14	Coffeetree (Gymnocladus dioica)	f
15	Cottonwood (Populus deltoides)	T
16	Crabapple (Malus coronaria)	I
17	Cucumbertree (Magnolia acuminata)	T
18	Dogwood (Cornus florida)	T
19	Elm (Ulmus spp)[3]	t
20	Elm (U. campestris)	t
21	Fringe-tree (Chionanthus virginica)	I
22	Ginkgo (Ginkgo biloba)	f
23	Hackberry (Celtis occidentalis)	I
24	Hawthorn (Crataegus spp)	I
25	Hawthorn (C. oxyacantha)	I

	Species	Toler-ance
	Broadleaf Trees (continued)	
26	Hickory (Carya spp)	f
27	Holly (Ilex opaca)	T
28	Honeylocust (Gleditsia triacanthos)	f
29	Hophornbeam (Ostrya virginiana)	T
30	Hornbeam (Carpinus caroliniana)	T
31	Horsechestnut (Aesculus hippocastanum)	f
32	Laurel (Umbellularia californica)	t
33	Locust (Robinia pseudoacacia)	T
34	Maple (Acer spp)[4]	T
35	Maple (Acer spp)[5]	t
36	Maple (A. platanoides)	T
37	Mountain-ash (Sorbus americana)	I
38	Mulberry (Morus rubra)	I
39	Oak (Quercus spp)[6]	I
40	Oak (Q. prinus)	f
41	Paper (Aalmia triloba)	f
42	Pecan (Carya illinoensis)	f
43	Poplar (Populus nigra)	T
44	Redbud (Cercis canadensis)	I
45	Serviceberry (Amelanchier arborea)	I
46	Sumac (Toxicodendron vernix)	t
47	Sweetgum (Liquidambar styraciflua)	f
48	Sycamore (Platanus occidentalis)	f
49	Tupelo (Nyssa sylvatica)	t
50	Walnut (Juglans nigra)	f

	Species	Toler-ance
	Broadleaf Trees (concluded)	
51	Willow (Salix spp)	T
52	Yellow-poplar (Liriodendron tulipifera)	f
	Conifers	
53	Baldcypress (Taxodium distichum)	I
54	Douglas-fir (Pseudotsuga menziesii)	I
55	Fir (Abies spp)[7]	T
56	Fir (Abies spp)[8]	t
57	Fir (A. procera)	f
58	Hemlock (Tsuga spp)[9]	T
59	Hemlock (T. mertensiana)	t
60	Larch (Larix spp)	f
61	Pine (Pinus spp)[10]	f
62	Pine (Pinus spp)[11]	T
63	Pine (Pinus spp)[12]	I
64	Redcedar (Juniperus virginiana)	f
65	Redcedar (Thuja plicata)	T
66	Port Orford cedar (Chamaecyparis lawsoniana)	t
67	Redwood (Sequoia sempervirens)	t
68	Sequoia (S. gigantea)	I
69	Spruce (Picea spp)[13]	t
70	Spruce (P. abies)	T
71	Spruce (P. pungens)	I
72	Torreya (Torreya californica)	T
73	White-cedar (Chamaecyparis thyoides)	T
74	White-cedar (Thuja occidentalis)	t
75	White-pine (Pinus strobus)	f

[1] F. americana, F. latifolia, F. nigra, F. pennsylvanica. [2] P. grandidentata, P. tremuloides. [3] U. americana, U. thomassi. [4] A. saccharum, A. spicatum. [5] A. rubrum, A. saccharinum. [6] Q. alba, Q. lobata, Q. macrocarpa, Q. palustris, Q. rubra, Q. velutina. [7] A. balsamea, A. lasiocarpa. [8] A. amabilis, A. grandis, A. concolor. [9] T. canadensis, T. heterophylla. [10] Pinus attenuata, P. contorta, P. couteri, P. echinata, P. jeffreyi, P. muricata, P. ponderosa, P. resinosa, P. rigida, P. taeda, P. virginiana. [11] P. banksiana, P. palustris, P. sabiniana, P. sylvestris. [12] Pinus elliottii, P. lambertiana, P. monticola, P. radiata, P. strobus. [13] Picea engelmannii, P. glauca, P. mariana, P. rubens, P. sitchensis.

390. EFFECT OF LIGHT ON VARIOUS PROCESSES: PLANTS

Part I: EFFECT OF WAVE LENGTH

Data present the effectiveness of brief dark-period interruption for control of flowering and certain vegetative expressions. For studies of the inhibition or promotion of flowering, plants growing under radiation from carbon arc and incandescent filament lamps for a daily period of about 12 hrs were subjected, at the midpoint of the dark-period, to radiation of known energy and wave length. Values represent relative energy and may be converted to kiloergs per sq cm by multiplying the values in this table by the following factors: cocklebur, 40; soybean, 30; barley (flowering) 35; henbane, 300; lettuce, 2; pea, 160; barley (elongation), 100; tomato, 200.

	Effect	Relative Energy Normalized to Maximum Response at Wave Length											
		4400 Å	4800 Å	5000 Å	5200 Å	5400 Å	5600 Å	5800 Å	6200 Å	6600 Å	6800 Å	7000 Å	7200-7600 Å
	Inhibition of flowering												reverses
1	Cocklebur (Xanthium pensylvanicum)	125	173	92	40	8	5.4	2.6	1	1.5	3.1	7	the
2	Soybean, Biloxi (Glycine soja)	18	27	17	6	3.7	2	1.3	1	1.3	1.6	3.5	response
	Promotion of flowering												caused
3	Barley, Wintex (Hordeum vulgare)	218	185	85	35	4	1.8	1.3	1	1.5	4	7	by
4	Henbane (Hyoscyamus niger)					4	1.8	1.3	1	1.5	4	7	red
	Promotion of germination												(6200-6600 Å) for items 1, 3, 4, 5, 7, and 8.
5	Lettuce, Grand Rapids (Lactuca sativa)						18	10	3	1	1.2	50	
	Promotion of leaf elongation												
6	Pea, Little Marvel (Pisum sativum)	100	190	200	95	24	10	6.5	1	1	1	1.3	
	Inhibition of stem elongation												
7	Barley, Coleseа I (Hordeum vulgare)	250		200	40	20	5	2	1.3	1	2	6	
	Production of pigmentation (fruit cuticle)												
8	Tomato, Rutgers (Lycopersicon esculentum)	30	30	30	30	20	10	3	1	1	1.2	7	

Part II: EFFECT OF DAY LENGTH ON DEVELOPMENT, EXCLUSIVE OF FLOWER INITIATION

	Process Affected	Day Length		Process Affected	Day Length		Process Affected	Day Length
	Winter hardening			Root thickening		15	Bud elongation	
1	Abelia (Abelia grandiflora)	Short	8	Radish (Raphanus sativus)	Short		Orchid (Cattleya trianae)	Short
2	Alfalfa (Medicago sativa)	Short		Bulb development			Pistillate flowers increased	
	Tuber development		9	Onion (Allium cepa)	Long	16	Cucumber (Cucumis sativus)	Short
3	Artichoke (Helianthus tuberosus)	Short		Runner development			Staminate flowers increased	
			10	Strawberry (Fragaria chiloensis)	Long	17	Cucumber (C. sativus)	Long
4	Potato (Solanum tuberosum)	Short		Stem elongation			Seed development	
5	Yam (Dioscorea alata)	Short	11	Coneflower (Rudbeckia spp)	Long	18	Hemp, staminate (Cannabis sativa)	Short
	Storage root development		12	Henbane, biennial (Hyoscyamus niger)	Long		Plastlet development	
6	Dahlia (Dahlia spp)	Short		Rye, winter (Secale cereale)	Long	19	Bryophyllum (Bryophyllum pinnatum)	Long
	Fibrous root development		13	Spinach (Spinacia oleracea)	Long			
7	Dahlia (Dahlia spp)	Long	14					

Part III: EFFECT OF VARIOUS DAY LENGTHS

	Species	Beginning of Test	Time Required for Development at Day Lengths												Photoperiodic Class
			10 hr			12 hr			12.5 hr			13 hr			
			Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	
			da		in	da		in	da		in	da		in	
1	Althea (Hibiscus syriacus)	Mar 27							95	117	30	96	123	48	Long day
2	Amaranth (Gomphrena globosa)	May 13	21	33	8	21	33	10	21	36	11	23	32	8	Day neutral
3	Balsam (Impatiens balsamina)	June 23	20	28	14	20	28	18				20	29	19	Day neutral
4	Bindweed (Convolvulus sepium)	May 19													Long day
5	Bougainvillea (Bougainvillea glabra)	May 24	28	45	38	36	57	40	69	88	56	96	157	60	Short day
6	Calendula (Calendula officinalis)	May 9	26	42	9	26	41	13	26	41	15	26	41	15	Day neutral
7	Caryopteris (Caryopteris incana)	June 5	26	38	13	26	38	16				24	35	16	Short day
8	Cloud grass (Agrostis nebulosa)	May 14										49	58	10	Long day
9	Cobaea (Cobaea scandens)	May 26	24	53	46	36	91	41				55	91	46	Short day
10	Columbine (Aquilegia caradensis)	Mar 27	4	25	19	4	28	19				4	36	30	Short day
11	Cosmos (Cosmos bipinnatus)	May 7	10	17	19	10	24	36	10	17	19	10	19	20	Day neutral
12	Gama-grass (Tripsacum dactyloides)	Mar 31	63	72	64	65	74	56	68	75	45	68	75	67	Short day
13	Goldenrod (Solidago ulmifolia)	Apr 23	39	73	25	45	73	22	69	88	14	49	77	19	Short day
14	Kalanchoe (Kalanchoe laxiflora)	May 8							173	239	38	173	199	47	Day neutral
15	Loosestrife (Steironema ciliatum)	Apr 15							56	65	21	87	93	24	Long day
16	Perilla (Perilla frutescens)	May 17	25	39	22	37	47	27	39	58	30	39	50	25	Short day
17	Periwinkle (Vinca minor)	June 7	18	26	16	18	23	12							Day neutral
18	Poinsettia (Euphorbia pulcherrima)	May 16	32	65	47	39	44	53	48	180	66	107	179	76	Short day
19	Purpletop (Tricdia flava)	May 20	29	38	26	39	44	25	39	46	37	42	47	30	Short day
20	Reed grass (Calamagrostis cinnoides)	Mar 30				30	76	41	63	88	42	70	98	35	Day neutral
21	Rosinweed (Silphium trifoliatum)	Apr 18	89	107	38	89	110	56	68	90	56	68	89	70	Long day
22	Soybean, Biloxi (Glycine soja)	May 25	20	23	9	21	27	14	24	27	18	25	31	16	Short day
23	Spider-flower (Cleome spinosa)	May 31	26	38	28	27	35	28				27	36	34	Day neutral
			3.5 hr			4 hr			4.5 hr			24 hr			
1	Althea (Hibiscus syriacus)	Mar 27	95	126	46	103	136	44	106	144	52	103	130	44	Long day
2	Amaranth (Gomphrena globosa)	May 13	21	33	9	21	41	15	21	35	12	18	32	10	Day neutral
3	Balsam (Impatiens balsamina)	June 23	20	28	17							30	38	21	Day neutral
4	Bindweed (Convolvulus sepium)	May 19	44	59	40							35	49	45	Long day
5	Bougainvillea (Bougainvillea glabra)	May 24	145	164	75	103	153	50	143	157	53	131	157		Short day
6	Calendula (Calendula officinalis)	May 9	26	47	20	26	41	18	26	44	20	26	41	17	Day neutral
7	Caryopteris (Caryopteris incana)	June 5				54	71	28				59	71	28	Short day
8	Cloud grass (Agrostis nebulosa)	May 14	48	58	13	37	45	11	35	41	16	34	48	11	Long day
9	Cobaea (Cobaea scandens)	May 26				60	92	60				64	97	60	Short day
10	Columbine (Aquilegia caradensis)	Mar 27				14	36	30				4	36	30	Short day
11	Cosmos (Cosmos bipinnatus)	May 7	10	15		10	21	19	10	24	26	10	19	17	Day neutral
12	Gama-grass (Tripsacum dactyloides)	Mar 31	68	76	58	81	89	56	82	89	60	82	89	65	Short day
13	Goldenrod (Solidago ulmifolia)	Apr 23	58	82	32	87	88	36	85	108	30	67	114	36	Short day
14	Kalanchoe (Kalanchoe laxiflora)	May 8				173	192	51	173	204	50	173	192	51	Day neutral
15	Loosestrife (Steironema ciliatum)	Apr 15	49	61	19	48	65	25	49	68	23	49	68	20	Long day
16	Perilla (Perilla frutescens)	May 17	49	70	38	53	83	41	62	96	47	93	114	50	Short day
17	Periwinkle (Vinca minor)	June 7										18	23	12	Day neutral
18	Poinsettia (Euphorbia pulcherrima)	May 16	162	191	74	163	193	76	163	195	91	158	197	70	Short day
19	Purpletop (Tricdia flava)	May 20	43	51	45	50	56	25	69	87	51	92	103	42	Short day
20	Reed grass (Calamagrostis cinnoides)	Mar 30	63	84	41	57	84	46	67	91	45	60	84	37	Day neutral
21	Rosinweed (Silphium trifoliatum)	Apr 18	65	89	83	65	89	76	54	79	54	54	78	57	Long day
22	Soybean, Biloxi (Glycine soja)	May 25	34	37	19	42	48	27	50	60	30	81	90	38	Short day
23	Spider-flower (Cleome spinosa)	May 31				28	40	36				28	38	65	Day neutral

391. EFFECT OF LIGHT, WITH TEMPERATURE INTERACTIONS, ON FLOWERING OF PLANTS

Temperature interactions and effects on photoperiodic classification are incomplete. Upon further investigations these data may become modified.

	Species	Photoperiodic Class and Light Period[1]	Temperature Interactions and Effects[2]
	Fruit and Vegetable Crops		
1	Artichoke (Helianthus tuberosus)	s, N	
2	Bean, lima (Phaseolus lunatus)	N, S	
3	Bean, string (P. vulgaris)	N, S[3]	
4	Beet, garden (Beta vulgaris)	l	Th, Tl, L
5	Cabbage (Brassica pekinensis)	l	Th, Tl, L
6	Chicory (Cichorium intybus)	L	Th, Tl, N
7	Carrot (Daucus carota)	N	Ve(4–10°C)
8	Celery (Apium graveolens)	N	Ve(4–10°C)
9	Cucumber (Cucumis sativus)	N	
10	Dill (Anethum graveolens)	L(>11 hr)	
11	Lettuce (Lactuca sativa)	l	Th, Tl, N
12	Onion (Allium cepa)	l, s, N	Tl
13	Pea (Pisum sativum)	N, l	
14	Pepper (Capsicum annuum)	N, s	TP
15	Potato (Solanum tuberosum)	l, s, N	
16	Radish (Raphanus sativus)	L	
17	Spinach (Spinacia oleracea)	L(>13 hr)	Ve[4]
18	Strawberry (Fragaria chiloensis)[5]	S(<10 hr)	Tq
19	Strawberry, everbearing (F. chiloensis)	l, N	
20	Sweetpotato (Ipomoea batatas)	S	
21	Tomato (Lycopersicon esculentum)	N, l, s	TP
22	Turnip (Brassica rapa)	l	
	Grasses		
23	Barley, spring (Hordeum vulgare)	l	Vo
24	Barley, winter (H. vulgare)	L(>12 hr)	Va(7–9°C)
25	Beardgrass (Andropogon gerardii)	S(<18 hr)	
26	Bentgrass (Agrostis palustris)	L(>16 hr)	
27	Bluegrass, annual (Poa annua)	N	Vo
28	Bluegrass, Kentucky (P. pratensis)	l	Th, Tl, N or s; Ve
29	Bromegrass (Bromus inermis)	L(>12.5 hr)	Va
30	Broomsedge (Andropogon virginicus)	L(12–14.5 hr)	
31	Canary-grass (Phalaris arundinacea)	L(>12.5 hr)	
32	Cloudgrass (Agrostis nebulosa)	L(>13 hr)	
33	Corn (Zea mays)	N, S	
34	Fescue (Festuca elatior)	L	
35	Foxtail (Alopecurus pratensis)	L(>9 hr)	
36	Oat (Avena sativa)	L(>9 hr)	Tl; Va, Vo[6]
37	Orchardgrass (Dactylis glomerata)	L(>12 hr)	Ve
38	Rice, summer (Oryza sativa)	N	Th
39	Rice, winter (O. sativa)	S(<12 hr)	Th
40	Rye, spring (Secale cereale)	l	Tl; Vo
41	Rye, winter (S. cereale)	l	Va
42	Ryegrass, Italian (Lolium italicum)	L(>11 hr)	Va
43	Ryegrass, early perennial (L. perenne)	L(>9 hr)	Ve
44	Ryegrass, late perennial (L. perenne)	L(>13 hr)	Ve
45	Sorghum (Sorghum vulgare)	l	
46	Sudan (Holcus sudanensis)	s	Th, Tl, N
47	Sugar cane (Saccharum officinarum)[5]	s	
48	Sugar cane, var. 28 NG 292	IM(12–14 hr)	
49	Timothy, hay (Phleum pratensis)	L(>12 hr)	
50	Timothy, pasture (P. nodosum)	L(>14.5 hr)	
51	Wheat, spring (Triticum sativum)	l	Va
52	Wheat, winter (T. sestivum)[5]	L(>12 hr)	Va
53	Wheatgrass (Agropyron smithii)	L(>10 hr)	
	Legumes and Other Field Crops		
54	Alfalfa (Medicago sativa)	l	Th, Tl, N[7]
55	Beet, sugar (Beta vulgaris)	L	Tl(7–9°C); Ve
56	Clover (Trifolium spp)[8]	L	
57	Clover (Trifolium spp)[9]	l	Tl
58	Clover, red (T. pratense)[10]	L(>12 hr)	
59	Cotton (Gossypium hirsutum)	N, s	Tq

	Species	Photoperiodic Class and Light Period[1]	Temperature Interactions and Effects[2]
	Legumes and Other Field Crops (concluded)		
60	Lespedeza (Lespedeza stipulacea)	S(<13.5 hr)	
61	Soybean, Biloxi and Mandarin (Glycine soja)	S-s	Th; Tq
62	Soybean, Mandell (G. soja)	s	Th; Tq
63	Sweetclover (Melilotus alba)	L	
64	Tobacco (Nicotiana tabacum)[5]	N	
65	Tobacco, Havana (N. tabacum)	l	
66	Tobacco, Md. Mammoth (N. tabacum)	S(<14 hr)	Th; <13°C, N
67	Vetch, spring (Vicia sativa)	l	Th, Tl, N
	Ornamental Plants		
68	Althea (Hibiscus syriacus)	L(>12 hr)	
69	Aster (Callistephus chinensis)	l	Th
70	Azalea, coral bell (Rhododendron sp)	N	
71	Balsam (Impatiens balsamina)	N	
72	Begonia (Begonia semperflorens)	N	Tl; Th, l
73	Bryophyllum (Bryophyllum pinnatum)	S(<12 hr)	
74	Cactus (Zygocactus truncatus)	s	Tl(18°C); 13°C, N
75	Chrysanthemum (Chrysanthemum frutescens)	L	
76	Chrysanthemum (C. indicum)	S(<15 hr)	Tq
77	Cineraria (Senecio cruentus)	s	
78	Cornflower (Centaurea cyanus)	l	Th; Tl, N
79	Cosmos (Cosmos bipinnatus)[5]	s	
80	Cosmos, Klondyke (C. sulphureus)	S(<14 hr)	Th and Tl
81	Cosmos, orange flare (C. sulphureus)	N	Th; Tl, S
82	Foxglove (Digitalis purpurea)	l	Ve
83	Fuchsia (Fuchsia hybrida)	N	Th
84	Gardenia (Gardenia jasminoides fort.)	N	
85	Geranium (Pelargonium hortorum)	N	Tl
86	Holly, English (Ilex aquifolium)	N	
87	Hydrangea (Hydrangea macrophylla)	N(?)	Ve
88	Kalanchoe (Kalanchoe blossfeldiana)	S(<12 hr)	
89	Larkspur (Delphinium cultorum)	L	Tl; Th, N
90	Morning glory (Ipomoea hederacea)	S	
91	Morning glory (I. purpurea)	s[11]	
92	Orchid (Cattleya trianae)	S	
93	Pansy (Viola tricolor)	N	Tl
94	Petunia (Petunia hybrida)	l	Th; Tl, N
95	Phlox (Phlox paniculata)	L	Th
96	Poinsettia (Euphorbia pulcherrima)	S(<12.5 hr)	Tl[12]
97	Salvia (Salvia splendens)	s	Th; Tl, N
98	Sedum (Sedum spectabile)	L(>13 hr)	
99	Snapdragon (Antirrhinum majus)	l	Th; Tl, N
100	Stock, German (Matthiola incana)	l	Th; Tl, N
101	Tephrosia (Tephrosia candida)	IM(10–13.2 hr)	
102	Violet (Viola papilionacea)	S(<11 hr)[13]	Th; Tq
	Field Weeds		
103	Cocklebur (Xanthium pennsylvanicum)	S(<15.5 hr)	Tq
104	Coneflower (Rudbeckia bicolor)	L(>10 hr)	Th
105	Coneflower (R. hirta)	L(>12 hr)	
106	Daisy (Chrysanthemum leucanthemum)	L	
107	Dog fennel (Anthemis cotula)	l	Th; Tl, N
108	Goldenrod (Solidago spp)[14]	S	
109	Henbane, annual (Hyoscyamus niger)	L(>10 hr)	Tq
110	Henbane, biennial (H. niger)	L	Tq; Ve
111	Jimson weed (Datura stramonium)	s[15]	
112	Lamb's-quarters (Chenopodium album)	S	
113	Mallow (Malva verticillata)	s	Th(23°C); 18°C, N
114	Nightshade (Solanum nigrum)	N	Tl; Th, l
115	Primrose, evening (Oenothera biennis)	l	Tl
116	Ragweed (Ambrosia artemisiifolia)	S	
117	Sow-thistle (Sonchus oleraceus)	l	
118	Tumbleweed (Amaranthus graecizans)	s	Th

/1/ L=long day required; l=long day favorable; S=short day required; s=short day favorable; N=day neutral; IM=intermediate. Where there is more than one symbol of classification, varietal differences occur, the most common class being entered first. Classification is followed in parentheses by light period for flowering (>12 hr should be interpreted as 12 hr or more; <12 hr, as 12 hr or less). /2/ Th=indicated photoperiodic response occurs at relatively low temperatures (plant may also flower at other day lengths at higher temperatures), or reproductive development is promoted by low temperatures during photoperiodic induction; Th=indicated response occurs at relatively high temperatures (plant may also flower at other day lengths at lower temperatures), or reproductive development is promoted by high temperatures during photoperiodic induction; Tq=temperature has a quantitative effect on the critical day length, i.e., an increase in temperature lowers the minimum limits for long day plants and raises the maximum limits for short day plants, or on the degree of photoperiodic response; Ve=vernalization or other low temperature preconditioning of embryo plants, seedlings, buds, or plants, previous to photoperiodic induction, is essential for complete reproduction development; Va=vernalization promotes reproductive development but is not essential; Vo=vernalization not effective; TP=thermoperiodic, i.e., development affected by alternation of temperature between day and night periods. /3/ Photoperiod influences fruit development but floral initiation is not affected. /4/ For some varieties. /5/ Data applicable to most varieties. /6/ Winter varieties, Va; spring varieties, Vo. /7/ Vegetative in warm nights. /8/ Species include crimson clover (T. incarnatum), Ladino clover (T. repens). /9/ Species include red clover (T. pratense), white clover (T. repens). /10/ Variety English Montgomery, for American Medium, l(>9 hr). /11/ Night temperature, 22°C. At 18°C, N; at 13°C, L. /12/ Night temperature, <21°C. At 13–14°C, L. /13/ Production of blue petaliferous flowers; formation of fertile, cleistogamous flowers, N. /14/ Species include: S. altissima, S. fistulosa, S. juncea. For S. cuticri, L. /15/ Becomes N with aging of plant.

Part I: SUMMATION OF DAY LENGTHS IN NORTHERN AND SOUTHERN LATITUDES, BEGINNING DECEMBER 21

Values for northern latitudes are followed in parentheses by those for southern latitudes.

	Date	Latitude	Daylight and Twilight Periods			Percentage Change when Compared with: Equator	Preceding Latitudes.
			Daylight[1] min	Twilight[2] min	Total min		
1		0°	8729(8729)	552(552)	9281(9281)		
2		10°	8312(9148)	552(552)	8864(9700)	-4. 5(+4. 5)	-4. 5(+4. 5)
3	Jan 1	20°	7870(9602)	576(600)	8446(10,202)	-9. 0(+9. 9)	-4. 7(+5. 2)
4		30°	7362(10, 129)	624(662)	7986(10, 791)	-14. 0(+16. 3)	-5. 4(+5. 8)
5		40°	6730(10, 796)	738(792)	7468(11, 588)	-19. 5(+24. 8)	-6. 5(+7. 4)
6		50°	5934(11, 767)	922(1072)	6856(12, 839)	-26. 1(+38. 3)	-8. 2(+10. 8)
7		0°	18, 913(18, 913)	1168(1168)	20, 081(20, 081)		
8		10°	18, 039(19, 793)	1192(1196)	19, 231(20, 989)	-4. 2(+4. 5)	-4. 2(+4. 5)
9	Jan 15	20°	17, 109(20, 749)	1248(1276)	18, 357(22, 024)	-8. 6(+9. 7)	-4. 5(+4. 9)
10		30°	16, 047(21, 857)	1352(1418)	17, 399(23, 275)	-13. 4(+15. 9)	-5. 2(+5. 7)
11		40°	14, 722(23, 263)	1578(1696)	16, 300(24, 959)	-18. 8(+24. 3)	-6. 3(+7. 2)
12		50°	12, 850(25, 293)	1974(2282)	14, 824(27, 575)	-26. 2(+37. 3)	-9. 0(+10. 5)
13		0°	31, 275(31, 275)	1916(1916)	33, 191(33, 191)		
14		10°	29, 925(32, 642)	1940(1962)	31, 865(34, 604)	-4. 0(+4. 2)	-4. 0(+4. 2)
15	Feb 1	20°	28, 494(34, 126)	2038(2086)	30, 532(36, 212)	-8. 0(+9. 1)	-4. 2(+4. 6)
16		30°	26, 859(35, 847)	2220(2316)	29, 079(38, 163)	-12. 4(+15. 0)	-4. 8(+5. 4)
17		40°	24, 828(38, 021)	2572(2752)	27, 400(40, 773)	-17. 4(+22. 8)	-5. 8(+6. 8)
18		50°	21, 974(41, 141)	3196(3654)	25, 170(44, 795)	-24. 2(+33. 5)	-8. 1(+9. 9)
19		0°	41, 453(41, 453)	2514(2514)	43, 967(43, 967)		
20		10°	39, 805(43, 135)	2556(2578)	42, 361(45, 713)	-3. 7(+4. 0)	-3. 7(+4. 0)
21	Feb 15	20°	38, 060(44, 959)	2682(2730)	40, 742(47, 689)	-7. 3(+8. 5)	-3. 8(+4. 3)
22		30°	36, 071(47, 074)	2920(3032)	38, 991(50, 106)	-11. 3(+14. 0)	-4. 3(+5. 1)
23		40°	33, 605(49, 230)	3360(3580)	36, 965(53, 316)	-15. 9(+21. 1)	-5. 2(+6. 4)
24		50°	30, 159(53, 543)	4152(4694)	34, 311(58, 237)	-22. 0(+32. 4)	-7. 2(+9. 2)
25		0°	52, 355(52, 355)	3144(3144)	55, 499(55, 499)		
26		10°	50, 499(54, 273)	3188(3244)	53, 687(57, 517)	-3. 3(+3. 6)	-3. 3(+3. 6)
27	Mar 1	20°	48, 536(56, 344)	3344(3412)	51, 880(59, 756)	-6. 5(+7. 7)	-3. 4(+3. 9)
28		30°	46, 299(58, 752)	3642(3780)	49, 941(62, 532)	-10. 0(+12. 7)	-3. 7(+5. 1)
29		40°	43, 539(61, 795)	4128(4344)	47, 723(66, 207)	-14. 4(+19. 4)	-4. 4(+5. 9)
30		50°	40, 393(66, 070)	5142(5738)	44, 835(71, 808)	-19. 2(+29. 4)	-6. 0(+8. 4)
31		0°	62, 527(62, 527)	3732(3732)	66, 259(66, 259)		
32		10°	60, 581(64, 561)	3788(3812)	64, 357(68, 373)	-2. 9(+3. 2)	-2. 9(+3. 2)
33	Mar 15	20°	58, 523(66, 750)	3960(4028)	62, 483(70, 778)	-5. 7(+6. 8)	-2. 9(+3. 5)
34		30°	56, 184(69, 257)	4314(4452)	60, 498(73, 749)	-8. 7(+11. 3)	-3. 2(+4. 2)
35		40°	53, 303(72, 497)	4904(5202)	58, 243(77, 699)	-12. 1(+17. 7)	-3. 7(+5. 4)
36		50°	49, 293(77, 034)	6038(6668)	55, 331(83, 702)	-16. 5(+26. 3)	-5. 0(+7. 7)
37		0°	74, 877(74, 877)	4446(4446)	79, 323(79, 323)		
38		10°	72, 972(76, 903)	4490(4526)	77, 462(81, 429)	-2. 3(+2. 6)	-2. 3(+2. 6)
39	Apr 1	20°	70, 954(79, 084)	4708(4776)	75, 662(83, 860)	-4. 6(+5. 7)	-2. 3(+3. 0)
40		30°	68, 668(81, 626)	5130(5268)	73, 798(86, 894)	-7. 0(+9. 5)	-2. 5(+3. 6)
41		40°	65, 856(84, 826)	5858(6120)	71, 714(90, 946)	-9. 6(+14. 6)	-2. 8(+4. 7)
42		50°	61, 943(89, 364)	7144(7764)	69, 087(97, 128)	-12. 9(+22. 4)	-3. 7(+6. 8)
43		0°	85, 050(85, 050)	5034(5034)	90, 084(90, 084)		
44		10°	83, 297(86, 949)	5078(5114)	88, 375(92, 063)	-1. 9(+2. 2)	-1. 9(+2. 2)
45	Apr 15	20°	81, 438(88, 996)	5324(5392)	86, 762(94, 388)	-3. 7(+4. 8)	-1. 9(+2. 5)
46		30°	79, 336(91, 393)	5810(5940)	85, 146(97, 333)	-5. 5(+8. 0)	-1. 9(+3. 1)
47		40°	76, 758(94, 617)	6638(6876)	83, 396(101, 293)	-7. 4(+12. 4)	-2. 0(+4. 1)
48		50°	73, 160(98, 718)	8084(8670)	81, 244(107, 388)	-9. 8(+19. 2)	-2. 6(+6. 0)
49		0°	96, 678(96, 678)	5908(5908)	102, 586(102, 586)		
50		10°	95, 221(98, 311)	5778(5800)	100, 999(104, 111)	-1. 4(+1. 7)	-1. 4(+1. 7)
51	May 1	20°	93, 674(100, 077)	6062(6110)	99, 736(106, 187)	-2. 6(+3. 7)	-1. 2(+2. 0)
52		30°	91, 942(102, 614)	6540(6722)	98, 552(109, 876)	-4. 7(+6. 3)	-1. 2(+2. 5)
53		40°	89, 813(104, 795)	7558(7766)	97, 371(112, 561)	-6. 9(+9. 9)	-1. 2(+3. 4)
54		50°	86, 836(108, 570)	9224(9734)	96, 060(118, 304)	-6. 2(+15. 5)	-1. 3(+5. 1)
55		0°	100, 855(100, 855)	6322(6322)	113, 177(113, 177)		
56		10°	105, 752(108, 153)	6394(6416)	112, 146(114, 569)	-0. 9(+1. 2)	-0. 9(+1. 2)
57	May 15	20°	104, 585(109, 564)	6712(6754)	111, 297(116, 318)	-1. 7(+2. 8)	-0. 8(+1. 5)
58		30°	103, 290(111, 238)	7338(7422)	110, 628(118, 660)	-2. 3(+4. 8)	-0. 6(+2. 0)
59		40°	101, 709(113, 383)	8406(8566)	110, 115(121, 949)	-2. 7(+7. 8)	-0. 5(+2. 8)
60		50°	99, 507(119, 484)	10, 300(10, 708)	109, 807(127, 192)	-3. 0(+12. 4)	-0. 3(+4. 3)
61		0°	119, 216(119, 216)	10700(10700)	126, 286(126, 286)		
62		10°	118, 634(120, 007)	7172(7172)	125, 806(127, 179)	-0. 4(+0. 7)	-0. 4(+0. 7)
63	June 1	20°	118, 033(120, 879)	7277(7302)	125, 561(128, 432)	-0. 6(+1. 7)	-0. 2(+1. 0)
64		30°	117, 391(121, 932)	8248(8302)	125, 639(130, 234)	-0. 5(+3. 1)	+0. 1(+1. 4)
65		40°	116, 636(123, 312)	9478(9572)	126, 114(132, 884)	-0. 1(+5. 2)	+0. 4(+2. 0)
66		50°	115, 608(125, 343)	11, 710(11, 952)	127, 318(137, 295)	+0. 8(+8. 7)	+1. 0(+3. 3)
67		0°	133, 762(133, 762)	7978(7978)	141, 740(141, 740)		
68		10°	133, 871(133, 871)	8092(8092)	141, 963(141, 963)	+0. 2(+0. 2)	+0. 2(+0. 2)
69	June 15	20°	134, 014(134, 014)	8516(8516)	142, 530(142, 530)	+0. 6(+0. 6)	+0. 4(+0. 4)
70		30°	134, 239(134, 239)	9342(9342)	143, 581(143, 581)	+1. 3(+1. 3)	+0. 7(+0. 7)
71		40°	134, 582(134, 582)	10, 790(10, 790)	145, 372(145, 372)	+2. 6(+2. 6)	+1. 2(+1. 2)
72		50°	135, 144(135, 144)	13, 482(13, 482)	148, 626(148, 626)	+4. 8(+4. 8)	+2. 2(+2. 2)

[1] Computed from time of sunrise to time of sunset. [2] Civil twilight.

Part II: PERCENTAGE DIFFERENCE IN SUMMATION OF DAY LENGTH BETWEEN NORTHERN AND SOUTHERN LATITUDES, BEGINNING DECEMBER 21

Percentage difference is presented in terms of southern latitudes.

Southern Latitude	Date	Northern Latitude 10° %	20° %	30° %	40° %	50° %
1	Jan 1	-8. 6	-12. 9	-17. 7	-23. 0	-29. 3
2	Feb 1	-7. 9	-11. 8	-16. 0	-20. 8	-27. 3
3	Mar 1	-6. 6	-9. 8	-13. 1	-17. 1	-22. 0
4	Apr 1	-4. 9	-7. 1	-9. 4	-11. 9	-15. 2
5	May 1	-3. 0	-4. 2	-5. 3	-6. 5	-7. 7
6	June 1	-1. 1	-1. 3	-1. 2	-0. 8	+0. 1
7	Jan 1	-13. 1	-17. 2	-21. 7	-26. 8	-32. 8
8	Feb 1	-12. 0	-15. 7	-19. 7	-24. 3	-30. 5
9	Mar 1	-10. 2	-13. 2	-16. 4	-20. 1	-25. 0
10	Apr 1	-7. 6	-9. 8	-12. 0	-14. 5	-17. 6
11	May 1	-4. 9	-6. 1	-7. 2	-8. 3	-9. 5
12	June 1	-2. 0	-2. 2	-2. 2	-1. 8	-0. 9
13	Jan 1	-17. 9	-21. 7	-26. 0	-30. 8	-36. 5
14	Feb 1	-16. 5	-20. 0	-23. 8	-28. 2	-34. 0
15	Mar 1	-14. 1	-17. 0	-20. 1	-23. 7	-28. 3
16	Apr 1	-10. 9	-12. 9	-15. 1	-17. 5	-20. 5
17	May 1	-7. 2	-8. 4	-9. 5	-10. 6	-11. 8
18	June 1	-3. 4	-3. 6	-3. 5	-3. 2	-2. 2
19	Jan 1	-23. 5	-27. 1	-31. 1	-35. 6	-40. 8
20	Feb 1	-21. 8	-25. 1	-28. 7	-32. 8	-38. 3
21	Mar 1	-18. 9	-21. 6	-24. 6	-27. 9	-32. 3
22	Apr 1	-14. 8	-16. 8	-18. 9	-21. 1	-24. 0
23	May 1	-10. 3	-11. 4	-12. 4	-13. 5	-14. 7
24	June 1	-5. 3	-5. 5	-5. 5	-5. 1	-4. 2
25	Jan 1	-31. 0	-34. 2	-37. 8	-41. 8	-46. 6
26	Feb 1	-28. 9	-31. 8	-35. 1	-38. 8	-43. 8
27	Mar 1	-25. 2	-27. 8	-30. 5	-33. 5	-37. 6
28	Apr 1	-20. 2	-22. 1	-24. 0	-26. 2	-28. 9
29	May 1	-14. 7	-15. 7	-16. 7	-17. 7	-18. 8
30	June 1	-8. 4	-8. 5	-8. 5	-8. 1	-7. 3

Part III: SEASONAL TIME SCALE OF DAY AND NIGHT HOURS

Northern Hemisphere	Dec 21	Jan 21	Feb 21	Mar 21	Apr 21	May 21	June 21
		Nov 21	Oct 21	Sept 21	Aug 21	July 21	
Par-allel	Period	Hours					
0°	Day	12. 0	12. 0	12. 0	12. 0	12. 0	12. 0
	Night	12. 0	12. 0	12. 0	12. 0	12. 0	12. 0
10°	Day	11. 5	11. 6	11. 7	12. 0	12. 3	12. 4
	Night	12. 5	12. 4	12. 3	12. 0	11. 7	11. 6
20°	Day	10. 8	11. 0	11. 4	12. 0	12. 6	13. 2
	Night	13. 2	13. 0	12. 6	12. 0	11. 4	11. 0
30°	Day	10. 2	10. 4	11. 1	12. 0	12. 9	13. 6
	Night	13. 8	13. 6	12. 9	12. 0	11. 1	10. 4
40°	Day	9. 3	9. 7	10. 6	12. 0	13. 4	14. 3
	Night	14. 7	14. 3	13. 4	12. 0	10. 6	9. 7
50°	Day	8. 0	8. 6	10. 1	12. 0	13. 9	15. 4
	Night	16. 0	15. 4	13. 9	12. 0	10. 1	8. 6
60°	Day	5. 9	6. 9	9. 2	12. 0	14. 8	17. 1
	Night	18. 1	17. 1	14. 8	12. 0	9. 2	6. 9
70°	Day	0	1. 5	7. 4	12. 0	16. 6	22. 5
	Night	24. 0	22. 5	16. 6	12. 0	7. 4	1. 5
80°	Day	0	0	0	12. 0	24. 0	24. 0
	Night	24. 0	24. 0	24. 0	12. 0	0	0
90°	Day	0	0	0	12. 0	24. 0	24. 0
	Night	24. 0	24. 0	24. 0	12. 0	0	0
Southern Hemisphere	June	May 21	Apr 21	Mar 21	Feb 21	Jan 21	Dec 21
		July 21	Aug 21	Sept 21	Oct 21	Nov 21	

Part IV: MEAN TEMPERATURES OF THE PARALLELS

	Parallel	Annual 0°_{C}	January 0°_{C}	July 0°_{C}
1	90°	-22. 7	-41	-1
2	75	-14. 7	-29. 0	3. 4
3 Northern	60	-1. 1	-16. 1	14. 1
4	45	9. 8	-1. 7	20. 9
5	30	20. 4	14. 5	27. 3
6	15	26. 3	24. 0	27. 9
7 Equator	0	26. 4	26. 4	25. 6
8	15	24. 4	25. 9	22. 3
9	30	18. 4	21. 9	14. 7
10	45	8. 8	12. 3	6. 2
11	60	-4. 1	1. 2	-10. 3
12 Southern	75	-18. 0	-3. 5	-29. 7
13	90	-30. 0	-11. 0	-42

393. GALVANOTAXIS AND OSCILLOTAXIS: ANIMALS

The term "galvanotaxis" is applied to the physiological response toward an electrode exhibited by an organism placed in a direct current field. If the organism aligns itself parallel to the current lines, and faces and migrates toward the anode, the response is termed "anodal galvanotaxis." Similarly, if the organism reacts in a like manner to stimulation from the cathode, the action is called "cathodal galvanotaxis." When a movement is started in one direction and then is reversed, the response is "biphasic." When an organism in an alternating current field takes a position at right angles to the current lines, and moves parallel to the electrode, the term "oscillotaxis" is used. A=anode; AG=anodal galvanotaxis; C=cathode; CG=cathodal galvanotaxis; BP=biphasic; OT=oscillotaxis; NR=no response; R=response (described in footnotes) not defined by other symbols.

Part I: GALVANOTAXIS

	Organism	Response
	Protozoa	
1	Rhizopoda Ameba diffluens	CG[1]
2	A. limax	CG[1]
3	A. proteus	CG[1]
4	A. verrucosa	CG[1]
5	A. dofleini	NR
	Flagellata	
6	Chilomonas paramecium	CG-AG[2]
7	Euglena viridis	NR[3]
8	Gonium pectorale	CG-AG[4]
9	Peridinium tabulatum	CG
10	Polytoma uvella	AG
11	Trachelomonas hispida	CG
12	Volvox aureus	CG-AG[4, 5]
13	V. globator	CG-AG[4, 5]
	Ciliata	
14	Balantidium duodeni	CG[6]
15	B. elongatum	CG[6]
16	B. entoxon	CG[6]
17	Bursaria truncatella	CG[7]
18	Chilodon cucullulus	CG[7]
19	Coleps hirtus	CG[7]
20	Colpidium colpoda	CG[7]
21	Colpoda cucullus	CG
22	Condylostoma patens	CG
23	Glaucoma pyriformis	CG
24	Halteria grandinella	CG
25	Leucophrys spatula	NR
26	Nyctotherus cordiformis	CG[8]
27	Opalina ranarum	CG-AG[2, 8]
28	Oxytricha fallax	CG-AG[2]
29	Paramecium aurelia	CG[9]
30	P. bursaria	CG[9]
31	P. caudatum	CG[9]
32	P. marium	CG[9]
33	P. putrinum	CG[9]
34	Pleuronema chrysalis	CG
35	Spirostomum ambiguum	CG[7]
36	Stentor coeruleus	CG
37	S. polymorphus	CG
38	S. roeseli	CG
39	Stylonychia mytilus	CG[7]
40	Urocentrum turbo	CG
41	Uronema marina	CG
42	Urostyla grandis	CG[7]
	Coelenterata	
43	Hydra fusca	R[10, 11]
44	H. viridis	R[10, 11]
45	Pelmatohydra oligactis	R[11, 12]
46	Pennaria tiarella	R[12]
47	Polyorchis penicillata	R[12]

	Organism	Response
	Platyhelminthes	
	Turbellaria	
48	Dendrocoelum lacteum	CG
49	Leptoplana variabilis	CG
50	Planaria agilis	CG[13, 14]
51	P. dorotocephala	CG[13, 14]
52	P. gonocephala	CG[13, 14]
53	P. maculata	CG[13, 14]
54	P. polychroa	CG[13, 14]
55	P. simplissima	CG[13, 14]
56	P. velata	CG[13, 14]
57	Polycelis nigra	CG[14]
58	Stenostoma leucops	CG[15]
	Nemertea	
59	Lineus socialis	CG[15]
60	L. viridis	CG[15]
	Echinodermata	
	Asteroidea	
61	Asterina gibbosa	BP-CG[16]
62	Asterias glacialis	BP
63	A. rubens	BP
64	A. tenuispina	BP
65	Astropecten bispinosus	BP
66	A. milleri	BP
67	A. spinulosus	BP
68	Echinaster sepositus	BP
69	Ophiotrix fragilis	AG[17]
70	Ophiura albida	AG
71	O. texturata	AG
72	Solaster papposus	BP-CG[16]
	Echinoidea	
73	Echinus milaris	NR[18]
74	Sphaerechinus granularis	CG[17]
75	Strongylocentrotus lividus	AG[17, 18]
76	S. drobachiensis	AG[17, 18]
	Echiuroidea	
77	Echiurus cryscocanthophrus	AG[13]
	Annelida	
	Chaetopoda	
78	Dasychone lucullana, larva	CG
79	Dero limosa	CG
80	Lumbricinereus inconstans	CG
81	Lumbricus terrestris	CG[14]
82	Nereis spp	R[14, 19]
83	Tubifex rivulorum	CG
	Hirudinea	
84	Hirudo medicinalis	R[20]
	Arthropoda	
	Crustacea	
85	Apus cancriformis	AG
86	Asellus aquaticus	AG
87	A. communis	AG

	Organism	Response
	Arthropoda (concluded)	
88	Astacus fluviatilis	AG[21, 22]
89	Bosmina longispina	AG or CG
90	Chydorus sphaericus	AG or CG
91	Cyclops viridis	AG or CG
92	C. strenuus	AG or CG
93	Cyclocypris ovum	CG
94	Cypridopsis incongruens	CG
95	Daphnia longisema	AG or CG
96	D. magna	AG or CG
97	D. pulex obtusa	AG or CG
98	Diaptomus denticornis	CG
99	D. gracilis	CG
100	D. tatricus	CG
101	Galathea squamifera	AG[22]
102	Gammarus spp	CG-AG[2, 23]
103	Homarus americanus	R[24]
104	Moina macrocopa	CG
105	Notodromas monacha	CG
106	Palaemonetes vulgaris	AG[22]
107	Simocephalus vetulus	AG or CG
	Myriopoda	
108	Isobates varicorms	AG
109	Lithobius validus	AG
110	Polydesmus complanatus	AG
	Insecta	
111	Corixa striata	AG
112	Dytiscus marginalis	AG
	Mollusca	
113	Limnaea stagnalis	CG
114	Planorbis	CG
	Vertebrata	
	Cyclostomata	
115	Petromyzon fluviatilis	AG
	Pisces	
116	Acerina cernua	AG
117	Apodes spp	AG
118	Cyprinus auratus	AG[25]
119	Esox spp	AG
120	Gastrosteus aculeatus	AG
121	Gobio fluviatilis	AG[25]
122	Leuciscus idus	AG
123	L. rutilus	AG
124	Phoxinus laevis	AG
125	Salmo, embryo	AG
126	Sardinops caerulae	AG
127	Tinca spp	AG
	Amphibia	
128	Ambystoma larvae	R[25, 26]
129	Rana, adult	NR
130	Rana, tadpole	CG-AG[2]
131	Triton spp	NR
132	Triturus torosus	R[25, 26]

/1/ AG after treatment with NH_4OH or NH_3 salts. AG when free from substrate. /2/ CG in weak (or medium) fields. AG in strong fields. /3/ Or CG or AG, depending upon culture. /4/ CG in light; AG in dark. /5/ AG after duration in current field. /6/ AG in moderately alkaline field. /6/ AG in moderately alkaline field. /7/ When fixed to substrate turns at right angles with current lines, peristome toward C. /8/ Fresh from frog intestine or with acid treatment. AG out of intestine or with alkali treatment. /9/ In strong field, after moderate currents of long duration, growth in 1/20 M NaCl, suspension in NaCl solution above 0.01-0.1 N, suspension in salt solutions at high concentration, organism may move towards A electrotophoretically with anterior end directed towards C. True AG in medium with low calcium concentration. /10/ When fixed bends toward A. /11/ When not fixed bends toward C. /12/ When fixed bends toward C. /13/ Reversed by strychnine. /14/ Bends concavely toward C when at right angles with field. /15/ Reversed by barium salts. /16/ BP, strong fields; CG, weak fields. /17/ Older larvae CG. /18/ Spines and tube feet AG. /19/ After long period in laboratory bends concavely toward A. /20/ Bends anteriorly toward C. /21/ CG in hypertonic salt solutions. /22/ At right angles with field, extremities facing A flexed, facing C extended. /23/ Acid promotes AG, alkali CG. /24/ Gather at, but not directed toward, A. /25/ Bends concavely toward A when at right angles with field. /26/ Bends ventrally concave facing A, dorsally concave facing C, when parallel with field.

Part II: OSCILLOTAXIS

	Organism	Response
	Protozoa	
1	Rhizopoda Ameba dolfeini	NR
2	A. proteus	OT
	Flagellata	
3	Peridinium umbonatum	R[1]
	Ciliata	
4	Aspidisca spp	R[2]
5	Chilodon spp	OT[3]
6	Colpidium colpoda	OT[3]
7	Euplotes spp	OT[4]
8	Onychodromus grandis	R[2]
9	Paramecium caudatum	OT[5]
10	Stentor polymorphus	NR[6]
11	Stylonychia mytilus	OT[2]

	Organism	Response
	Protozoa (concluded)	
12	Vorticella campanulata	NR[7]
	Platyhelminthes	
13	Dendrocoelum lacteum	OT
	Annelida	
14	Hirudo medicinalis	OT
	Arthropoda	
	Crustacea	
15	Asellus aquaticus	OT
16	Gammarus pulex	OT
17	Palaemon serratus	OT
18	Penerus caramote	OT
19	Portunus olsatus	OT
20	Potamobius leptodactylus	OT

	Organism	Response
	Arthropoda (concluded)	
21	Insecta Aeschna larvae	OT
22	Dytiscus marginalis	OT
	Vertebrata	
23	Pisces Cyprinus auratus	OT
24	Esox lucius	OT
25	Gastrosteus aculeatus	OT
26	Perca fluviatilis	OT
27	Phoxinus laevis	OT
28	Rhodeus amarus	OT
29	Salmo lacustris	OT
30	Amphibia Rana esculenta, tadpole	OT

/1/ Swims in cliques with long axes at right angles with current. /2/ Swims backwards in circles. /3/ Anterior part describes circle around point in posterior part of organism. /4/ Strong field. Swims in direction of current in weak field. /5/ May make rotary movements with anterior end; posterior end stationary with body describing cone (double cone in stronger field); middle of organism stationary. /6/ Rotation around longitudinal axis accelerated. /7/ When unattached swims in circles.

Part I: EFFECTS ON BIOLOGICAL MATERIALS AT PRESSURES IN EXCESS OF 1000 ATMOSPHERES

	Material	Approximate Pressure, Atmospheres	Results of Compression
	Tissues and Tumors		
1	Carcinoma, Brown-Pearce	1000[1]	Resistant.
2	Chick heart, embryonic	1000-1850	Reduction of subsequent growth in culture.
3	Erythrocytes	500-3000	Rounded.
4		5000	Disintegrated.
5	Sarcoma transplants, rat	1800	Inactivated.
	Bacteria and Fungi		
6	Bacillus anthracis	3000	Partial loss of virulence; death of vegetative cells.
7	Bacteria, colon	3000	Unaffected.
8	Bacteria, various spp	5000	Vegetative cells killed.
9	Spores, bacterial	12,000	Killed.
10	Staphylococci	3000	Unaffected.
11	Streptococci	3000	Killed or retarded in growth.
12	Yeast cells	4000-6000	Death, preceded by cytoplasmic flocculation or coagulation.
	Viruses		
13	Avian pest (fowl plague)	4000	Inactivated, but retained antigenicity.
14	Bacteriophage vs.: Bacillus megatherium	7000	Inactivated.
15	B. subtilis	7000	Inactivated.
16	Salmonella typhosa	7000	Inactivated.
17	Staphylococci	2000	Inactivated.
18	Encephalomyelitis (rabbit)	7000	Inactivated.
19	Foot and mouth disease	4000	Inactivated.
20	(in guinea pig)	3000	Attenuated.
21	Herpes (rabbit)	3000	Inactivated.
22	Papilloma	4000	No tumors.
23	Rabies (rabbit)	4000	Attenuated.
24		5000	Inactivated.
25	Rous sarcoma	1800	Tumors delayed.
26	Sarcoma filtrate	4000	No tumors.
27	Shope papilloma	1800	Tumors delayed.
28	Tobacco mosaic	7500	Inactivated; coagulated.
29		8000-8700	Inactivated.
30	Tobacco necrosis	3000-5000	Inactivated.
31	Vaccinia (rabbit)	4500	Inactivated.
32	Yellow fever (monkey)	3000	Slightly attenuated.

	Material	Approximate Pressure, Atmospheres	Results of Compression
	Antigens and Antibodies		
33	Antigen, equine serum	6000	Specificity may be changed or unchanged.
34	Antitoxin, tetanus, equine	13,500	Gelated, partially inactivated.
35	Filtrate, S. typhi	6000	Superior to cells as immunizing antigen.
36	Toxin, diphtheria	13,500	Partially destroyed.
37		17,600	Mostly destroyed.
38	Toxin, tetanus	13,500	Greatly attenuated or inactivated.
39	Tuberculin	13,500	Not destroyed.
40	Venom, cobra	13,500	Lethality unchanged.
	Enzymes		
41	Amylase, laccase, lipase, sucrase(yeast), trypsin(pancreatic), trypsinogen	8,000-15,000	Some completely, others partially inactivated.
42	Chymotrypsinogen	7600	pH 3. 1-7. 6: partly inactivated.
43	Chymotrypsin, trypsin	7600	pH 3: scarcely affected; pH 7. 6: partially inactivated.
44	Pepsin	7600	pH 2-5. 2: largely inactivated.
45	Pepsin, rennin	6000	Inactivated.
46	Ribonucleodepolymerase	6000	Reversible diminution in activity under pressure (pressure also affects polymerization of ribonucleic acid alone).
	Proteins		
47	Albumin, egg	5000	Slight stiffening.
48		7000	Completely coagulated.
49		7500	Denatured, coagulated, SH groups exposed.
50	Amylase (active) plus its starch digest	6000	Resynthesis of product resembling initial undigested material.
51	Carboxyhemoglobin	9000	Coagulated.
52	Gelatin	2000	Gelation accelerated.
53	Gelatin gel	3000	Water squeezed out.
54	Globulin, serum (equine)	3,000-13,000	Gelated.
55	Insulin	10,000	Coagulated, but not physiologically inactivated.
56	Trypsin (active) plus its gelatin or serum albumin digest	6000	Resynthesis of product resembling initial undigested material.

[1] Transplantability destroyed by pressure of 1800 atmospheres.

Part II: PHYSIOLOGICAL EFFECTS ON BIOLOGICAL MATERIALS AT PRESSURES NOT EXCEEDING 1000 ATMOSPHERES

	Material or Activity	Pressure, Atmospheres	Results of Compression
			Cell Division
1	Eggs (Arbacia)	100-400	Progressive reversible solation of gelated cortical cytoplasm.
2		400	Reversible regression of cleavage furrows; reversible solation of cortical plasmagel.
3	Eggs (annelid, echinoderm, and vertebrate)	100-500	Cleavage-inhibiting pressure increases with temperature (5-30°C).
4	Eggs (Ascaris)	800	Exceptionally resistant to pressure; division not inhibited.
5	Eggs, marine (miscellaneous)	200-400	Reversible inhibition of cleavage.
6	Eggs (Trochis)	300-400	Reversible solation of spindles and asters; movements of chromosomes stopped.
			Other Cellular Activities
7	Amebold movement (A. proteus, A. dubia)	200-500	Reversible solation of plasmagel; collapsing of pseudopodia; stopping of movement. At higher temperatures greater pressures required to produce effects.
8	Bioluminescence (bacterial)	200-400	Effect depends on temperature. Light intensity decreases at lower, increases at higher, temperature.
9	Ciliary movement	200-400	Temporary increase in beat frequency with each increase of pressure; reverse effect with pressure decrements.
10	"Contraction" of pigment cells (fish)	200-400	"Contraction" phase reversibly inhibited; totally inhibited at higher level.
11	Heart rate, tissue cultured fragments (frog heart)	300	Effect depends on temperature; retardation at lower temperatures, acceleration at higher temperatures.
12	Muscular contraction	200-400	Effect depends on temperature. Tension decreases at lower, increases at higher, temperatures.
13	Protoplasmic streaming (Elodea)	200-400	Solation of cytoplasm; streaming slowed; stopped at 400 atmospheres; reversible.
14	(Pelomyxa)	200-400	Solation of plasmagel; streaming stopped.

Part III: EFFECTS ON RATE OF SPECIFIC ENZYME REACTIONS AT PRESSURES LESS THAN 680 ATMOSPHERES

Net volume changes of activation computed according to observed influences of pressure.

	Enzyme		Substrate		pH	Temp °C	Observed Volume Change ml/mol
	Kind	Conc mg/ml	Kind	Conc			
1	Amylase, pancreatic	Commercial	Starch	2%		22-23	-28
2	Amylase, salivary	Commercial	Starch	1%		22-23	-22
3	Chymotrypsin, crystal	0.00154	Casein	1%	7.7	14.5	-13.5
4		0.0148	L-Tyrosine, ethyl ester	0.02 M	7.8	25.1	-13.5
5	Dehydrogenase, formic		Na formate		5.6-9.5	30	0
6	Invertase	Commercial	Sucrose	10%	4.8	30	-3
7			Sucrose	10%	7.04	30	-5
8			Sucrose	10%	7.03-70.7	35-45	-69†
9	Lipase, pancreatic	Commercial	Tributyrin	Very low		22-23	-13
10	Lysozyme	0.0015	Micrococcus lysodeikticus (whole cells)	$\geq 10^9$ cells per ml	6.2-8.7	25	-10 to -24
11	Pepsin	Commercial	Gelatin	0.83%		22-23	-22
12	Trypsin, crystal	0.062	a-Benzoyl-1-arginin-amide	0.04 M	7.76	84.5	-1
13		0.076	a-Benzoyl-1-arginin-amide isopropyl ester	0.011 M	8.1	25.2	0
14				0.04 M	7.76	25.1	0
15		0.076	p-Lactoglobulin	0.5%	8.1	25.1	-36
16		0.5	Casein	0.68%	7.3	55	-1
17				0.68%	7.3	25-35	-5 to -10

/1/ Acceleration in observed rate under pressure at these temperatures attributed to retardation by pressure of enzyme dehydration, proceeding with a large volume increase.

395. EFFECTS OF ACCELERATION: MAN

"G" denotes accelerative force in terms of the magnitude of force of gravity at the earth's surface. "Positive G" designates that the force vector acts parallel to the long axis of the body, from foot to head; "transverse G", that force vector acts transverse (perpendicular) to the long axis of the body, and may be (a) prone (from chest to back),or (b) supine (from back to chest). "Negative G" refers to a force vector acting parallel to the long axis of the body from head to foot.

Part I: TOLERANCE TO POSITIVE G

Data are for relaxed young healthy males exposed for 10 seconds. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

	Reaction	G
1	Grayout (Loss of peripheral vision)[1]	4.3(3-5.6)
2	Blackout (Loss of central vision)[1]	4.9(3.4-6.4)
3	Unconsciousness	5.5(3.7-7.3)

/1/ Grayout and blackout for at least 5 sec of 10 sec period.

Part II: G-TOLERANCE TIME LIMITS

Data are for young healthy males actively resisting G. Tolerance limit is unconsciousness. Values in parentheses are ranges of estimates.

	Direction of Force	Time in Seconds .001	.01	0.1	1.0	10	100	1000
1	Positive G	70	(30-40)	(19-22.5)	12.5	(6.5-8.2)	(3.5-5.5)	3.5
2	Transverse G	200	(60-100)	(38-55)	(25-27.5)	(15-17.5)	(7.2-12.5)	8.5
3	Negative G	15	(9.5-16.5)	(6.5-10)	(4.5-6.5)	(3.2-3.8)	(2.2-2.5)	1.5

Part III: G-FORCES ACTING UPON MAN AND AIRCRAFT IN FLIGHT

Section 1: Various Turns

Values in parentheses indicate time in seconds required for a 360° turn.

	Speed mi/hr	Radius of Turn (Statute Miles) 0.5	1.0	2.0	5.0	10.0	Speed knots/hr	Radius of Turn (Nautical Miles) 0.5	1.0	2.0	5.0	10.0	G
		G	G	G	G	G		G	G	G	G	G	
1	100	1.03 (113)	1.01 (226)	1.00 (452)	1.00 (1131)	1.00 (2262)	13 100	1.04 (113)	1.01 (226)	1.00 (452)	1.00 (1131)	1.00 (2262)	
2	200	1.42 (56)	1.12 (113)	1.03 (226)	1.01 (565)	1.00 (1131)	14 200	1.53 (56)	1.16 (113)	1.04 (226)	1.01 (565)	1.00 (1131)	
3	300	2.49 (38)	1.52 (75)	1.15 (151)	1.03 (377)	1.01 (754)	15 300	2.80 (38)	1.65 (75)	1.20 (151)	1.03 (377)	1.01 (754)	
4	400	4.17 (28)	2.26 (57)	1.42 (114)	1.08 (283)	1.02 (565)	16 400	4.76 (28)	2.54 (57)	1.53 (114)	1.10 (283)	1.02 (565)	
5	500	6.41 (23)	3.32 (45)	1.87 (90)	1.18 (225)	1.05 (452)	17 500	7.36 (23)	3.78 (45)	2.08 (90)	1.23 (225)	1.07 (452)	
6	600	9.18 (19)	4.67 (38)	2.49 (76)	1.35 (188)	1.10 (377)	18 600	10.55 (19)	5.35 (38)	2.81 (76)	1.45 (188)	1.13 (377)	
7	700	12.50 (16)	6.28 (32)	3.26 (64)	1.60 (161)	1.18 (323)	19 700	14.30 (16)	7.21 (32)	3.70 (64)	1.74 (161)	1.23 (323)	
8	800	16.25 (14)	8.15 (28)	4.17 (56)	1.91 (141)	1.29 (283)	20 800	18.70 (14)	9.39 (28)	4.76 (56)	2.11 (141)	1.36 (283)	
9	900	20.60 (13)	10.28 (25)	5.24 (50)	2.28 (126)	1.43 (251)	21 900	23.61 (13)	11.85 (25)	6.00 (50)	2.56 (126)	1.54 (251)	
10	1000	25.35 (11)	12.70 (23)	6.41 (46)	2.72 (113)	1.61 (226)	22 1000	29.21 (11)	14.60 (23)	7.35 (46)	3.08 (113)	1.76 (226)	
11	1500	57.00 (7)	28.55 (15)	14.30 (30)	5.80 (75)	3.02 (151)	23 1500	65.80 (7)	32.90 (15)	16.45 (30)	6.64 (75)	3.43 (151)	
12	2000	101.30 (6)	50.70 (11)	25.40 (23)	10.20 (57)	5.16 (113)	24 2000	117.00 (6)	58.40 (11)	29.20 (23)	11.70 (57)	5.91 (113)	

Section 2: Standard 3°/sec Turn

Full turn requires 120 seconds.

	Speed mi/hr	Radius, Statute Miles	G	Speed knots/hr	Radius, Nautical Miles	G
1	100	0.53	1.03	13 100	0.53	1.03
2	200	1.06	1.11	14 200	1.06	1.14
3	300	1.59	1.23	15 300	1.59	1.29
4	400	2.12	1.38	16 400	2.12	1.49
5	500	2.65	1.56	17 500	2.65	1.70
6	600	3.18	1.75	18 600	3.18	1.93
7	700	3.71	1.95	19 700	3.71	2.16
8	800	4.24	2.16	20 800	4.24	2.42
9	900	4.77	2.48	21 900	4.77	2.67
10	1000	5.31	2.59	22 1000	5.31	2.93
11	1500	7.96	3.72	23 1500	7.96	4.25
12	2000	10.61	4.88	24 2000	10.61	5.57

A = mass number; α = alpha particle; β^+ = positive beta particle from nucleus; β^- = negative beta particle from nucleus; γ = gamma ray; EC = electron capture; Mev = million electron volts; n = neutron; Z = atomic number.

	Isotope			Half-life	Radiation			Average β-Energy[2] Mev
	Z	Symbol	A		η_1[1]	Type	Mev	
1	0	n	1	13 min	100	β^-	0.78	
2	1	H	3	12.4 yr	100	β^-	0.018	0.0057
3	4	Be	7	53.6 da	100	EC[3]		
4	6	C	14	5570 yr	100	β^-	0.155	0.050
5	11	Na	22	2.6 yr	90	β^+	0.541	0.225
					10	EC[3]		
7					100	γ	1.28	
8	11	Na	24	15.1 hr	100	β^-	1.39	0.540
9					100	γ	1.37	
10					100	γ	2.75	
11	15	P	32	14.3 da	100	β^-	1.71	0.70
12	16	S	35	87.1 da	100	β^-	0.167	0.055
13	17	Cl	36	$\sim 3 \times 10^5$ yr	100	β^-	0.714	0.24
14	19	K	42	12.52 hr	18	β^-	1.99	
15					82	β^-	3.55	1.395
16					18	γ	1.53	
17	20	Ca	45	164 da	100	β^-	0.254	0.075
18	20	Ca	47	4.8 da	83	β^-	0.66	
19					17	β^-	1.94	
20					~17	γ	1.31	
21	21	Sc	46	85 da	~100	β^-	0.36	0.117
22					~100	γ	0.89	
23					~100	γ	1.12	
24	24	Cr	51	27.7 da	100	EC[3]		
25					~10	γ	0.32	
26	25	Mn	52	5.7 da	33	β^+	0.58	0.084
27					67	EC[3]		
28					100	γ	0.73	
29					100	γ	0.94	
30					100	γ	1.45	
31	25	Mn	54	291 da	100	EC[3]		
32					100	γ	0.84	
33	26	Fe	55	2.94 yr	100	EC[3]		
34						γ	cont[4]	
35	26	Fe	59	45 da	~46	β^-	0.271	
36					~54	β^-	0.462	0.120
37					3	γ	0.191	
38					57	γ	1.10	
39					43	γ	1.29	
40	27	Co	57	270 da	100	EC[3]		
41					~90	γ	0.014	
42					~90	γ	0.123	
43					~10	γ	0.137	
44	27	Co	60	5.38 yr	~100	β^-	0.306	0.099
45					~100	γ	1.17	
46					100	γ	1.33	
47	28	Ni	63	85 yr	100	β^-	0.063	0.022
48	29	Cu	64	12.84 hr	38	β^-	0.573	0.12
49					19	β^+	0.656	
50					43	EC[3]		
51					0.4	γ	1.34	
52	30	Zn	65	245 da	1.5	β^+	0.325	0.003
53					98.5	EC[3]		
54					46	γ	1.11	
55	33	As	77	38.7 hr	2	β^-	0.43	
56					98	β^-	0.68	
57						γ 1-7[5]	0.023-0.53	
58	34	Se	75	127 da	100	β^-	0.467	
59						γ	0.136	
60						γ 1-11[5]	0.025-0.40	
61	35	Br	82	35.9 hr	100	β^-	0.45	0.150
62						γ	0.55-2.0	
63	37	Rb	86	18.6 da	10	β^-	0.68	
64					90	β^-	1.77	
65					10	γ	1.08	
66	38	Sr	89	50.5 da	100	β^-	1.46	0.49
67	38	Sr	90	28 yr	100	β^-	0.53	
68	42	Mo	99	68 hr	14	β^-	0.45	
69					85	β^-	0.87	
70					85	β^-	1.23	
71						γ 1-6[5]	0.041-0.780	
72	47	Ag	110	270 da	35	β^-	0.09	
73					10	β^-	0.31	
74					50	β^-	0.57	
75					5	β^-	2.86	
76						γ 1-14[5]	0.116-1.51	
77	47	Ag	111	7.5 da	8	β^-	0.70	0.36
78					1	β^-	0.80	
79					91	β^-	1.04	
80					1	γ	0.247	
81					8	γ	0.340	
82	50	Sn	113	112 da	100	EC[3]		
83					100	γ	0.393	
84	51	Sb	124	60 da	10	β^-	0.22	
85					53	β^-	0.61	
86					6	β^-	0.87	
87					5	β^-	1.58	
88					5	β^-	1.66	
89					21	β^-	2.31	
90						γ 1-6[5]	0.603-2.07	
91	53	I	131	8.05 da	2.8	β^-	0.250	
92					9.3	β^-	0.335	0.189
93					87.2	β^-	0.606	
94					0.7	β^-	0.807	
95					6.3	γ	0.080	
96					0.7	γ	0.163	
97					6.3	γ	0.284	
98					80.9	γ	0.364	
99					9.3	γ	0.638	
100					2.8	γ	0.723	
101	55	Cs	134	2.3 yr	32	β^-	0.083	
102					5	β^-	0.31	
103					50	β^-	0.655	
104					13	β^-	0.683	
105						γ 1-15[5]	0.200-1.37	
106	55	Cs	137	30^{+3} yr	92	β^-	0.518	0.19
107					8	β^-	1.18	
108					92	γ	0.662	
109	56	Ba	140	13 da	40	β^-	0.48	
110					60	β^-	1.02	0.25
111						γ 1-6[5]	0.03-0.54	
112	58	Ce	144	282 da	20	β^-	0.16	
113					5	β^-	0.26	
114					75	β^-	0.33	
115						γ 1-8[5]	0.03-0.15	
116	59	Pr	143	13.8 da	100	β^-	0.93	
117	63	Eu	152	13 yr		β^-	0.70	
118						EC[3]		
119						γ 1-7[5]	0.12-1.09	
120	63	Eu	154	16 yr		β^-	1.45	
121						EC[3]		
122						γ	0.12	
123						γ	1.12	
124						γ	1.42	
125	77	Ir	192	74.4 da	44	β^-	<0.6	
126					50	β^-	0.67	
127					6	EC[3]		
128						γ 1-20[5]	0.14-1.16	
129	79	Au	198	2.70 da	99	γ	0.958	
130					100	γ	0.411	
131	79	Au	199	3.16 da	20	β^-	0.25	
132					73	β^-	0.30	0.098
133					7	β^-	0.46	
134					5	γ	0.05	
135					78	γ	0.16	
136					15	γ	0.21	
137	80	Hg	203	47 da	100	β^-	0.210	0.07
138					100	γ	0.279	
139	82	Pb	210	19 yr	100	β^-	0.018	0.006
140					100	α	0.047	
141	83	Bi	210	5.0 da	100	β^-	1.17	0.33
142	88	Ra	226	1620 yr	6	α	4.61	
143					94	α	4.79	
144					6	γ	0.18	
145	90	Th	232	1.39×10^{10} yr	25	α	3.95	
146					75	α	4.00	
147					25	γ	0.05	
148	92	U	232	74 yr	~ 32	α	5.261	
149					68	α	5.318	
150					32	γ	0.06	
151	92	U	233	1.62×10^5 yr	2	α	4.72	
152					15	α	4.77	
153					83	α	4.82	
154						γ 1-3[5]	0.04-0.09	
155	92	U	238	4.51×10^9 yr	22	α	4.13	
156					78	α	4.18	
157					22	γ	0.05	
158	94	Pu	238	90 yr	0.1	α	5.35	
159					~28	α	5.45	
160					72	α	5.50	
161						γ 1-3[5]	0.04-0.15	
162	94	Pu	239	2.44×10^4 yr	11	α	5.10	
163					89	α	5.15	
164						γ 1-5[5]	0.04-0.38	

/1/ Per cent disintegration in which radiation is emitted. /2/ Average energy of all β particles per disintegration. /3/ Electron capture, accompanied by X-rays characteristic of the daughter element. /4/ Continuous X-ray spectrum. /5/ Multiple γ rays with energies in the range indicated; branching ratios not established.

397. RADIOISOTOPES. METABOLIC FEATURES

A = mass number; α = alpha particles; β = beta particles; γ = gamma rays; Z = atomic number.

Isotope				Half-life	Radiation	Absorption	Localization	Elimination
	Z	Symbol	A					
1	11	Na	24	15.1 hr	β, γ	Complete	General	Rapid
2	15	P	32	14.3 da	β	Excellent	Bone; general	Few weeks[1]
3	20	Ca	45	164 da	β	Moderate	Bone	Slow[1]
4	38	Sr	89	50.5 da	β	Excellent	Bone	Slow[1]
5	38	Sr	90	28 yr	β	Excellent	Bone	Very slow[1]
6	39	Y	91	57 da	β, γ	Poor[2]	Bone	Very slow[1]
7	40	Zr	95	65 da	β, γ	Poor[2]	Bone	Slow[1]
8	41	Nb	95	35 da	β, γ	Slight	Bone	Slow[1]
9	44	Ru	103	42 da	β, γ	Poor[2]	Kidney	Few weeks
10	44	Ru	106	1 yr	β	Poor[2]	Kidney	Few weeks
11	52	Te	127	90 da	γ	Moderate	Kidney	Few weeks
12	52	Te	129	32 da	γ	Moderate	Kidney	Few weeks
13	53	I	131	8.05 da	β, γ	Complete	Thyroid	Month
14	55	Cs	134	2.3 yr	β, γ	Complete	Muscle; general	Fairly rapid
15	55	Cs	137	30 ± 3 yr	β, γ	Complete	Muscle; general	Fairly rapid
16	56	Ba	140	13 da	β, γ	Good	Bone	Very slow[1]
17	57	La	140	40 hr	β, γ	Poor[2]	Bone; liver	Few weeks[1, 3]
18	58	Ce	139	140 da	γ (soft)	Poor[2]	Bone; liver	Slow[1, 3]
19	58	Ce	141	32.5 da	β, γ	Poor[2]	Bone; liver	Slow[1, 3]
20	58	Ce	144	282 da	β, γ	Poor[2]	Bone; liver	Slow[1, 3]
21	59	Pr	143	13.8 da	β	Slight	Bone; liver	Slow[1, 3]
22	61	Pm	147	2.6 yr	β	Poor[2]	Bone; liver	Slow[1, 3]
23	84	Po	210	138.3 da	α, γ	Good	Kidney	Slow
24	88	Ra	226	1620 yr	α, γ	Good	Bone	Almost nil[1]
25	92	U	238	4.51 × 10^9 yr	α	Poor[2]	Lung; kidney	Slow
26	94	Pu	239	2.44 × 10^4 yr	α, γ	Very poor[2]	Lung; bone	Almost nil[1]

/1/ Retention in bones is usually a matter of months, approaching a year or more in the case of Sr and Y, and becoming virtually permanent in case of Ra and Pu. /2/ Poorly absorbed isotopes, if in sufficient concentration, may damage the gastrointestinal tract during passage; they also tend to be retained in the lung if and when they gain access. /3/ Liver retention is about 10 days in experimental animals, and kidney retention about 20 days.

398. RADIOISOTOPES: POSSIBLE TELETHERAPY SOURCES

Teletherapy refers to therapeutic irradiation with collimated (parallel) gamma rays.

c = curie; Mev = million electron volts; n = neutron; r = roentgen.

Isotope			Half-life	Gamma Energy	Practical Clinical Form	Production	Highest Practical-Volume Specific Activity[1]	Specific Gamma Exposure Rate[2]
	Z	Symbol	A	Mev			c/ml	r/c-hr at 1 m
1	88	Ra	226	1620 yr	0, 2-2. 2	Sulfate	Natural	4	0. 843
2	55	Cs	137	30 ± 3 yr	0, 661	Sulfate	Fission	100	0. 39
3	63	Eu	152, 154	13, 16 yr	1, 04	Oxide	Nuclear reactor	5000	0. 70
4	27	Co	60	5.38 yr	1. 17, 1. 33	Metal	Nuclear reactor	1000	1. 35
5	55	Cs	134	2.3 yr	0. 5-1. 3	Sulfate	Nuclear reactor	1000	1. 20
6	58	Ce	144	282 da	0. 6-2. 6[5]	Oxide	Fission	2000	0. 20
7	47	Ag	110	270 da	0. 6-1. 5	Metal	Nuclear reactor	250	1. 40
8	69	Tm	170	129 da	0. 08	Oxide	Nuclear reactor	500	0. 01
9	73	Ta	182	115 da	0. 04-1. 2	Metal	Nuclear reactor	1500	0. 8
10	21	Sc	46	84 da	0. 9-1. 1	Oxide	Nuclear reactor	500	1. 1
11	65	Tb	160	72.5 da	0. 1-1. 1	Chloride	Nuclear reactor	50	0. 3
12	77	Ir	192	74.4 da	0. 1-0. 6	Metal	Nuclear reactor	1000	0. 3

/1/ One year irradiation in 5 × 10^{13} n/cm2/sec, 1 yr after removal from reactor, ideal geometry, for neutron reactions. /2/ Assuming that gamma absorption in the source is negligible. /3/ Assuming the source is sealed within a 0. 5 mm-thick platinum capsule. /4/ Following filtration with 3 mm lead, 83% of total radiation appears to be from four high-energy photons averaging 1. 08 mev. /5/ Gamma activity from 17 min praseodymium daughter; energy levels are doubtful.

399. RADIOISOTOPES PRODUCED BY THE CYCLOTRON

Adapted from National Bureau of Standards Handbook 52 "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," and from Nuclear Science & Engineering Corp. Catalogue.

	Radioisotope	Half-life	Mode of Disintegration	Maximum Energy		Critical Organ	Element Concentration	Daily Intake of Element	Use
				Beta, Mev	Gamma, Mev[1]	weight, kg	g/kg		
1	Arsenic 73	76 da	K		0.011(X), 0.014, 0.052	Kidneys, 0.3			
2	Arsenic 74	17.5 da	β- (30%); β+ (35%); K (35%)	0.7, 1.4, 0.92, 1.53	0.011(X), 0.511, 0.59, 0.64	Kidneys, 0.3			
3	Beryllium 7	54.5 da	K		0.00011(X), 0.48 (~ 11%)	Bone, 7.0			
4	Cobalt 56	80 da	β+; K	1.5	0.0069(X), 0.511, 0.845, 1.26, 1.74, 2.01, 2.55, 3.25	Liver, 1.7	2.0 × 10^{-4}		Tracer studies.
5						Spleen, 0.15	4.7 × 10^{-4}		
6	Cobalt 57	270 da	β+	0.26	0.014, 0.119, 0.131, 0.511	Liver, 1.7	2.0 × 10^{-4}	Trace	
7						Spleen, 0.15	4.7 × 10^{-4}		
8	Cobalt 58	70 da	β+ (14.5%), K	0.47	0.0069(X), 0.511, 0.81	Liver, 1.7	2.0 × 10^{-4}		
9						Spleen, 0.15	4.7 × 10^{-4}		
10	Gold 195	180 da	K		0.067(X)	Kidneys, 0.3	Trace	-	
11	Iron 55	2.94 yr	K		0.0064(X)	Blood, 5.0	0.5	12 mg	Blood studies; iron turn-over.
12	Manganese 52	6 da	β+ (35%), K (65%)	0.582	0.0059(X), 0.511, 0.73, 0.94, 1.46	Kidneys, 0.3	6.0 × 10^{-4}	4 mg	Tracer studies.
13						Liver, 1.7	1.7 × 10^{-3}		
14	Manganese 54	310 da	K		0.0059(X), 0.835	Kidneys, 0.3	6.0 × 10^{-4}		
15						Liver, 1.7	1.7 × 10^{-3}		
16	Sodium 22	2.6 yr	β+	0.58	0.511, 1.28	Total body, 70.0	1.5	4.0 g	Circulatory studies.
17	Strontium 85	65 da	K		0.014(X), 0.513	Bone, 7.0	6 × 10^{-4}	0.3 mg	
18	Tungsten 181	140 da	K		0.058(X)	Bone, 7.0			
19	Zinc 65	250 da	β+ (3%); K (97%)	0.32	0.0086(X), 0.511, 1.11	Bone, 7.0	0.1	17 mg	Tracer studies.

/1/ (X) indicates K X-rays.

400. RADIOISOTOPES PRODUCED BY THE NUCLEAR CHAIN REACTOR

β^- = nuclear negatron; β^+ = nuclear positron; e⁻ = electron; K = electron capture from K ring; Mev = million electron volts; EC = electron capture.

	Isotope	Half-life	Maximum Energy of Radiation		Internal Dosages Determination			Isotope Intake, per da	Investigative or Therapeutic Use
			Beta	Gamma	Effective Energy per Disintegration Mev	Highest Isotope Concentration: Tissue wt, kg[1]	Isotope, g/kg tissue		
1	Arsenic-76	26.8 hr	1.29, 2.49, 3.04	0.55, 1.20, 1.70	1.1	Kidneys, 0.3			Trace element metabolism.
2	Calcium-45	164 da	0.254		0.085	Bone, 7.0	150	800 mg	Muscle, bone metabolism.
3	Carbon-14	5570 yr	0.155		0.053	Adipoae, 10	750	300 g	Protein, fat, carbohydrate, drug metabolism.
4	Chlorine-36	3.08×10^5 yr	0.714		0.260	Total body, 70	1.5	6.7 g	Electrolyte balance.
5	Cobalt-60	5.38 yr	0.306	1.17, 1.33	0.72, 0.55	Liver, 1.7	2×10^{-4}		External and interstitial radiotherapy.
6						Spleen, 0.15	4.7×10^{-4}	Trace	Trace element metabolism.
7	Copper-64	12.84 hr	0.571β⁻, 0.657β⁺	1.35	0.11	Liver, 1.7	6×10^{-3}	2 mg	Trace element metabolism.
8	Iodine-131	8.05 da	0.34, 0.61, 0.81, 0.25	0.64, 0.72, 0.36, 0.16, 0.28, 0.08	0.224	Thyroid, 0.02	0.52	0.2 mg	Thyroid function, iodine metabolism, determination of blood volume and brain tumors.
9	Iron-55	2.94 yr	EC		0.006	Blood, 5.0	0.5	12 mg	Iron, hemoglobin metabolism.
10	Iron-59	45 da	0.26, 0.46	1.10, 1.30	0.54	Blood, 5.0	0.5	12 mg	
11	Mercury-197	2.71 da	EC	0.08, 0.191					Distribution of mercurial diuretics.
12	Mercury-203	47 da	0.208	0.279					
13	Phosphorus-32	14.3 da	1.701		0.68	Bone, 7.0	69	1.4 g	Therapy, diagnosis of blood dyscrasias; metabolism of nucleoproteins, phospholipids; phosphate tracers.
14	Potassium-42	12.52 hr	2.04, 3.58	1.51	1.59	Muscle, 30.0	3	2.8 g	Mineral metabolism, electrolyte balance.
15	Sodium-24	15.1 hr	1.39	1.37, 2.75	2.7	Total body, 70	1.5	4.0 g	Hemodynamic function, mineral metabolism, and electrolyte balance.
16	Strontium-89	50.5 da	1.46		0.55	Bone, 7.0	0.06	0.3 mg	Metabolism and toxicity.
17	Strontium-90	28 yr	0.61		1.0	Bone, 7.0	0.06	0.3 mg	External radiotherapy.
18	Sulfur-35	87.1 da	0.167		0.055	Skin, 2.0	9	1.3 g	Metabolism of S-containing compounds.
19	Tritium (H-3)	12.4 yr	0.018		0.006	Total body, 70	100	250 g	Protein, carbohydrate, fat metabolism.
20	Zinc-65	245 da	EC, 0.325β⁺	1.12	0.085	Bone, 7.0	0.1	17 mg	Trace element metabolism.

/1/ Values for standard 70 kg man, determined at Chalk River Conference, Chalk River, Canada, September 29-30, 1949.

401. RADIATIONS: PHYSICAL PROPERTIES AND RELATIVE BIOLOGICAL EFFECTIVENESS

	Corpuscular[1]					Electromagnetic		
	Radiation	Physical Atomic Wt.	Mass g	Charge[2]	Composition	RBE[3]	Radiation	Wave Length[3] cm	RBE[3]
1	Alpha (α)[4]	4.00275	6.6442×10^{-24}	2⁺	2 neutrons, 2 protons	20	9 Electric waves	6×10^{12} to 1×10^{6}	
2	Beta (β⁻ or β⁺)[5]	0.0005486	9.11×10^{-28}	1⁻ or 1⁺	Fundamental particle	1	10 Radio waves	5×10^{6} to 8×10^{-2}	
3	Deuteron (d)[6]	2.01418	3.3433×1	1⁺	1 neutron, 1 proton	~1	11 Infrared rays	3×10^{-2} to 8×10^{-5}	
4	Electron or negatron (e⁻)[7]	0.0005486	9.11×10^{-28}	1⁻	Fundamental particle	1	12 Visible light rays	8×10^{-5} to 4×10^{-5}	
							13 Ultraviolet rays	4×10^{-5} to 8×10^{-7}	
5	Positron (e⁺)	0.0005486	9.11×10^{-28}	1⁺	Fundamental particle	1	14 X-rays[10] (0.1 - 3.0 Mev	2×10^{-6} to 3×10^{-10}	1
6	Proton (p)[8]	1.00758	1.67×10^{-24}	1⁺	Fundamental particle	10	15 Gamma rays (γ)[10]	2×10^{-8} to 6×10^{-11}	0.6-1
7	Neutron (n), fast	1.00894	1.67×10^{-24}	Neutral	Fundamental particle	10	16 Cosmic rays[11]	Variable	~1-10
8	Neutron (n), slow	1.00894	1.67×10^{-24}	Neutral	Fundamental particle	5			

/1/ Meson and neutrino are not included as they probably are unimportant biologically. /2/ Unit charge = 4.8025×10^{-10} electrostatic units (esu), 1.60203×10^{-20} electromagnetic units (emu). /3/ Relative biological effectiveness, calculated as ratios of rep (roentgen equivalent physical), the amount of ionizing radiation from which tissue will absorb energy to the extent of 93 ergs/g (x-radiation = 1). /4/ Helium nuclei. /5/ The term "beta" (β) is reserved for electrons[negatrons (β⁻) and positrons (β⁺)] of nuclear origin, as distinct from orbital electrons. /6/ Deuterium nuclei. /7/ Electrons[negatrons (e⁻)] of extra-nuclear origin, and cathode rays. /8/ Hydrogen nuclei. /9/ Approximate; some overlapping occurs. /10/ x- and gamma ray (photons) mass units equal (0.00107 for 1 Mev. /11/ Consist of electrons, protons, mesons, secondary pair production; below altitudes of 70,000 ft biological significance is questionable.

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402. RADIUM, COBALT-60, AND CESIUM-137 TELETHERAPY: PROTECTION REQUIREMENTS

For additional information see National Bureau of Standards Handbook 54.

Part I: LEAD PRIMARY PROTECTIVE BARRIER REQUIREMENTS[1]

r/hr/m = roentgens per hour at 1 meter.

	Radium	Lead, in cm, Required at a Distance of:			Cobalt-60	Lead, in cm, Required at a Distance of:			Cesium-137	Lead, in cm, Required at a Distance of:		
	mg	30 cm	1 m	2 m	r/hr/m	30 cm	1 m	2 m	r/hr/m	30 cm	1 m	2 m
						48 hr/wk						
1	25	6.6	1.9	0	0.1	9.4	5.5	3.0	0.01	2.7	0.7	0
2	50	8.1	3.3	0.7	0.3	11.3	7.5	5.0	0.03	3.7	1.65	0.35
3	75	9.0	4.0	1.3	1.0	13.4	9.5	7.1	0.1	4.85	2.8	
4	100	9.6	4.6	1.9	3.0	15.4	11.4	9.0	0.3	5.9	3.8	
5	200	11.1	6.0	3.3	10.0	17.7	13.6	11.1	1.0	7.0	4.95	
						12 hr/wk						
6	25	3.8	0	0	0.1	7.0	3.0	0.6	0.01	1.4	0	0
7	50	5.2	0.7	0	0.3	8.9	5.0	2.6	0.03	2.4	0.35	0
8	75	6.1	1.3	0	1.0	11.0	7.2	4.7	0.1	3.55	1.5	0.15
9	100	6.6	1.9	0	3.0	13.0	9.1	6.6	0.3	4.6	2.55	1.2
10	200	8.1	3.3	0.7	10.0	15.1	11.1	8.6	1.0	5.75	3.65	2.35
						6 hr/wk						
11	25	2.5	0	0	0.1	5.8	1.8	0	0.01	0.8	0	0
12	50	3.8	0	0	0.3	7.7	3.9	1.3	0.03	1.75	0	0
13	75	4.6	0.3	0	1.0	9.7	5.9	3.5	0.1	2.95	0.9	0
14	100	5.2	0.7	0	3.0	11.7	7.8	5.4	0.3	3.95	1.9	0.55
15	200	6.6	1.9	0	10.0	13.9	10.0	7.5	1.0	5.05	3.0	1.7

/1/ Shielding required to reduce radiation exposure to 0.3 r/wk.

402. RADIUM, COBALT-60, AND CESIUM-137 TELETHERAPY: PROTECTION REQUIREMENTS (Concluded)

For additional information see National Bureau of Standards Handbook 54.

Part II: PROTECTIVE BARRIER REQUIREMENTS

Work load equal to 80,000 roentgens per week at 1 meter. r = roentgen; HVL = half-value layer.

	For Primary-Protective Barrier										For Scattered Radiation[1]				
	Distance (Source to Occupied Space)		Radium			Cobalt-60			Cesium-137			Distance (Scatterer to Occupied Space)	Radium and Cobalt-60		Cesium-137
			Concrete	Steel	Lead	Concrete	Steel	Lead	Concrete	Steel	Lead		Concrete	Lead	Concrete	Lead
	m	ft	cm	cm	cm	cm	cm	cm	cm	cm	cm	m	ft	cm	cm	cm
1	3	9.8	108	34	23.1	96.5	32	19.2	76.2	27.7	9.6	3	9.8	30.2	1.8	24.9	0.9
2	3.1	10	106.7	34	23.1	96.5	32	19.2	76.2	27.7	9.5	3.1	10	27.4	1.8	24.6	0.9
3	4	13.1	101.6	32	21.6	91.4	30	18.2	73.7	33.6	9.0	4	13.1	24.4	1.5	21.8	0.7
4	4.6	15	99.1	31	20.9	88.9	29.5	17.6	71.1	23.1	8.8	4.6	15	22.9	1.4	20.3	0.7
5	5	16.4	96.5	30.5	20.4	87.6	29	17.4	69.9	22.6	8.6	5	16.4	21.8	1.3	19.3	0.6
6	6.1	20	92.7	29	19.3	83.8	27.4	16.6	66	21.6	8.2	6.1	20	19.8	1.1	17.5	0.5
7	7	23	90.2	27.9	18.6	81.3	26.4	16.1	64.8	21.1	7.9	7	23	18	1.1	16	0.5
8	7.6	25	87.6	27.4	18.1	80	25.9	15.7	63.5	20.8	7.8	7.6	25	17.3	0.9	15.2	0.4
9	8	26.3	87.6	27.4	17.9	79.4	25.9	15.6	63.5	20.1	7.7	8	26.3	16.5	0.8	14.5	0.4
10	9.2	30	85.1	26.4	17.2	77.5	24.9	15.1	58.4	19.8	7.5	9.2	30	15	0.7	13	0.3
11	10	32.8	82.6	25.9	16.8	74.9	24.4	14.8	57.2	19.3	7.3	10	32.8	14	0.7	12.2	0.3
12	Approximate HVL thickness		6,6	2.3	1.3	6.4	2.3	1.2	4.8	1.7	0.6	Approximate HVL thickness		4.1	3.3[2]	3.6	1.9[2]

/1/ Shielding required to reduce the 90° scattered radiation to 0.3 r/wk for a work load of 80,000 r/wk at 1 m and occupancy factor of 1 (full occupancy); the barrier for leakage radiation will depend upon the leakage permitted by the source housing. /2/ Values only for estimating purposes, since they vary considerably over the range of attenuations.

Part III: DISTANCE-EXPOSURE RELATIONSHIPS

Relation between distance and millicurie-hour for an exposure of 0.3 roentgen from an unshielded source.

	Milli-curie	Distance to Source							Milli-curie	Distance to Source					
		Radium		Cobalt-60		Cesium-137				Radium		Cobalt-60		Cesium-137	
	hr	ft	m	ft	m	ft	m		hr	ft	m	ft	m	ft	m
1	10	0.5	0.15	0.7	0.21	0.4	0.12	5	1000	5.5	1.68	7.0	2.13	3.7	1.13
2	30	1.0	0.30	1.2	0.37	0.6	0.18	6	3000	9.5	2.90	12	3.66	6.5	1.98
3	100	1.8	0.55	2.2	0.67	1.2	0.37	7	10,000	18.0	5.48	22	6.71	12	3.66
4	300	3.0	0.91	3.8	1.16	2.1	0.64								

403. X-RADIATION: PROTECTION

For additional information,see National Bureau of Standards Handbooks 50 and 60.

concr = concrete; kv = kilovolt; kvp = kilovolt peak; ma = milliampere.

Part I: PRIMARY PROTECTIVE BARRIER REQUIREMENTS

	Target Distance		For 10 ma at Pulsating Potentials[1] and Distances Indicated		For 400 kvp Pulsating Potential with Reflection Target			For 500 kv Constant Potential with Transmission Target			For 1000 kv Constant Potential with Transmission Target			For 2000 kvp Pulsating Potential with Transmission Target		
					Target Current											
			75 kv	150 kv	250 kv	1 ma	3 ma	5 ma	1 ma	3 ma	5 ma	1 ma	3 ma	5 ma	0.5 ma	1.0 ma	1.5 ma
			Barrier Thickness													
			Lead			Lead			Lead	Concr[2]	Lead	Concr[2]	Lead	Concr[2]	Concrete[2]		
	ft	m	mm	mm	mm	mm	mm	mm	mm	cm	mm	cm	mm	cm	cm	cm	cm
1	2	0,61	2, 2	4, 3	11, 8												
2	3	0,91	2, 0	4, 0	10, 9												
3	5	1,52	1, 7	3,6	9,6	16,5	20, 0	22,0	36	45,7	44	54,6	123	77,5	136	85,1	108,0	114,3	118.1
4	8	2,44	1,5	3,2	8,5	14.0	17,0	18,5	30	40,6	39	49,5	113	71,1	125	77,5	100,3	106,7	110,5
5	10	3,05	1,3	3,0	8,1	12,5	15,5	17,0	29	38.1	37	47,0	107	68,6	120	74,9	97,8	102,9	106,7
6	15	4,57	1,1	2,6	7,1	11,0	13,5	14,5	25	34,3	33	43,2	97	62,2	110	69,9	90,2	96,5	100,3
7	20	6,10	1,0	2,4	6,4	9,5	11,5	13,0	22	31,8	30	40,6	91	58,4	103	66,0	86,4	91,4	95,3
8	50	15,24	0,5	1.7	4,3	5,5	8,0	9,0	14	21,6	21	30,5	69	47,0	82	53,3	71,1	76,2	80,0
9	100	30,48							8	15,2	15	24,1	53	38,1	66	45,7	59,7	64,8	68,6
10	Approximate HVL thickness[3]		1,8		0,3	0,8		2,0									5,8		
11	Radiation filter		0.5mm Sn of Al		1.0mm Sn of Al	0.4mm of Sn, plus 0.75mm Cu and 2mm Al			2mm of W, plus 2.8mm Cu, 2.1mm brass, and 1.87mm of H_2O			2.8mm of W, plus 2.8mm Cu, 2.1mm of brass, and 18.7mm of H_2O			1.6mm of W, plus 5.1mm Cu and 6.8mm of H_2O		

/1/ X-rays excited by direct current potentials require approximately 10% greater thickness. /2/ Density, 147 lb/cu ft. /3/ HVL = half value layer.

Part II: DISTANCE PROTECTION

Values are distances at which no shielding is necessary.

	Target Current	50 kvp		75 kvp		100 kvp		150 kvp		200 kvp		250 kvp		400 kvp		500 kvp		1000 kvp		2000 kvp	
	ma	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
1	0,005	15	4, 57	20	6, 10	25	7, 62	20	6, 10	25	7, 62	25	7, 62	25	7, 62	30	9, 14	90	27, 43	195	59, 44
2	0, 01	20	6, 10	25	7, 62	30	9, 14	25	7, 62	30	9, 14	35	10, 67	35	10, 67	40	12, 19	115	35, 05	240	73, 15
3	0, 025	30	9, 14	40	12, 19	45	13, 72	45	13, 72	50	15, 24	55	16, 76	55	16, 76	60	18, 29	175	53, 34	370	112, 78
4	0, 05	40	12, 19	50	15, 24	60	18, 29	60	18, 29	65	19, 81	70	21, 34	70	21, 34	75	22, 86	220	67, 06	460	140, 21
5	0, 1	50	15, 24	70	21, 34	80	24, 38	80	24, 38	90	27, 43	95	28, 96	95	28, 96	110	33, 53	275	83, 82	560	164, 39
6	0, 25	70	21, 34	95	25, 91	115	35, 05	115	35, 05	125	38, 10	135	41, 45	135	41, 45	155	47, 24	380	115, 82	720	219, 46
7	0, 5	85	25, 91	115	35, 05	145	44, 20	145	44, 20	165	50, 29	170	51, 82	170	51, 82	200	60, 96	460	140, 21	850	259, 08
8	1, 0	100	30, 48	145	44, 20	180	54, 86	185	56, 39	205	62, 48	215	65, 53	215	65, 53	255	77, 72	550	167, 64	980	298, 70
9	2, 0	115	35, 05	175	53, 34	220	67, 06	225	68, 58	255	77, 72	270	82, 30	270	82, 30	320	97, 54	640	195, 07	1080	329, 18
10	2, 5	120	36, 58	185	56, 39	235	71, 63	245	74, 68	270	82, 30	285	86, 87	295	89, 92	340	103, 63	690	210, 31		
11	5, 0	140	42, 67	220	67, 06	280	85, 34	295	89, 92	330	100, 58	350	106, 68	360	109, 73	410	124, 97				
12	10, 0	160	48, 77	250	76, 20	330	100, 58	350	106, 68	390	118, 87	420	128, 02								
13	15, 0	175	53, 34	270	82, 30	355	108, 20	390	118, 87	430	131, 06	460	140, 21								
14	20, 0	185	56, 39	290	88, 39	380	115, 82	410	124, 97	460	140, 21	490	149, 35								
15	25, 0	195	59, 94	300	91, 44	390	118, 87	420	128, 02	480	146, 30	510	155, 45								

404. MAXIMUM PERMISSIBLE QUANTITY OF RADIOISOTOPES IN TOTAL BODY, AIR, AND WATER FOR CONTINUOUS EXPOSURE

Body intake is by ingestion and inhalation only. It is considered that any mixture of the radioisotopes listed is permissible, if the accumulated body burden in any organ, or the concentration in the contents of the gastrointestinal tract, does not reach a value that delivers a dose exceeding the maximum permissible dose-rate of 0.3 rem/wk. Explanations of the formulae and their use in calculating the values presented in this table may be obtained from Report of Subcommittee II on Permissible Dose For Internal Radiation, International Committee on Radiation Protection, and from Handbook 52 of the National Bureau of Standards.

A = mass number; α = alpha particles; β = beta particles; dr = daughter element; e⁻ = electron; γ = gamma rays; K = K type disintegration with α-ray emission; μc = microcurie; rem = roentgen equivalent man; Z = atomic number; s. = soluble; i. = insoluble.

	Radioisotope		Critical Organ[1]		Maximum Permissible Total Body Burden[2]	Maximum Permissible Concentration	
	Z	Symbol A	Type of Decay	Organ	wt. kg		In H_2O	In Air
						μc	μc/ml	μc/ml
1	1	H^3 (HTO or H_2O^{3})	β⁻	Total body	70	10,000	0.2	1×10^{-5}
2	4	Be^7	K, γ	Bone	7	725	1.0	5×10^{-6}
3	6	C^{14} as $(CO_2)^3$	β⁻	Fat	10	260	3×10^{-3}	1×10^{-5}
4	9	F^{18}	β⁺	Bone	7	5	0.2	3×10^{-5}
5	11	Na^{24}	β⁻, γ	Total body	70	15	8×10^{-3}	2×10^{-7}
6	15	P^{32}	β⁻	Bone	7	10	2×10^{-4}	1×10^{-7}
7	16	S^{35}	β⁻	Skin	2	300	5×10^{-3}	6×10^{-7}
8	17	Cl^{36}	β⁻	Total body	70	230	4×10^{-3}	6×10^{-7}
9	18	A^{41}	β⁻	Total body	70	33	5×10^{-4}	5×10^{-7}
10	19	K^{42}	β⁻, γ	Muscle	30	21	1×10^{-2}	2×10^{-6}
11	20	Ca^{45}	β⁻	Bone	7	14	1×10^{-4}	8×10^{-9}
12	21	Sc^{46}	β⁻, γ	Spleen	0.15	6	0.4	7×10^{-8}
				Liver	1.7	5	0.3	5×10^{-8}
13	21	Sc^{47}	β⁻	Spleen	0.15	15	4.0	9×10^{-7}
				Liver	1.7	11	3.0	6×10^{-7}
14	21	Sc^{48}	β⁻, γ	Spleen	0.15	5	3.0	6×10^{-7}
				Liver	1.7	3	1.0	3×10^{-7}
15	18	V^{48}	K, β⁺, γ	Bone	7	10	0.3	4×10^{-6}
16	24	Cr^{51}	K, γ	Kidneys	0.3	600	0.7	1×10^{-5}
17	25	Mn^{56}	β⁻, γ	Kidneys	0.3	25	0.15	4×10^{-6}
				Liver	1.7	8	0.4	4×10^{-6}
18	26	Fe^{55}	K	Blood	5.4	1000	5×10^{-3}	7×10^{-7}
19	26	Fe^{59}	β⁻, γ	Blood	5.4	13	1×10^{-3}	2×10^{-8}
20	27	Co^{60}	β⁻, γ	Liver	1.7	3	2×10^{-2}	2×10^{-7}
21	28	Ni^{59}	K	Liver	1.7	42	0.3	2×10^{-5}
22	29	Cu^{64}	K, β⁻, β⁺, γ	Liver	1.7	120	6×10^{-2}	5×10^{-6}
23	30	Zn^{65}	K, β⁺, γ	Bone	7	400	6×10^{-2}	2×10^{-6}
24	31	Ga^{72}	β⁻, γ	Bone	7	3	3	1×10^{-6}
25	32	Ge^{71}	K	Kidneys	0.3	72	10	4×10^{-5}
26	33	As^{76}	β⁻, γ	Kidneys	0.3	11	0.2	2×10^{-6}
27	37	Rb^{86}	β⁻, γ	Muscle	30	64	3×10^{-3}	4×10^{-7}
28	38	Sr^{89}	β⁻	Bone	7	2	1×10^{-5}	8×10^{-9}
29	38	Sr^{90} + Y^{90} [4]	β⁻	Bone	7	1	8×10^{-7}	2×10^{-10}
30	39	Y^{91}	β⁻	Bone	7	3	4×10^{-4}	9×10^{-8}
31	40	Zr^{95} + Nb^{95}	β⁻, γ	Bone	7	10	0.4	3×10^{-6}
32	41	Nb^{95}	β⁻, γ	Bone	7	44	2×10^{-3}	2×10^{-7}
33	42	Mo^{99}	β⁻, γ	Bone	7	17	5	6×10^{-4}
34	43	Tc^{96}	K, γ	Kidneys	0.3	5	3×10^{-2}	4×10^{-6}
35	44	Ru^{106} + Rh^{106} [4]	β⁻, γ	Kidneys	0.3	4	0.1	3×10^{-8}
36	45	Rh^{105}	β⁻, γ	Kidneys	0.3	9	0.4	2×10^{-6}
37	46	Pd^{103} + Rh^{103} [4]	K, e⁻	Kidneys	0.3	7	1×10^{-2}	2×10^{-6}
38	47	Ag^{105}	K, γ	Liver	1.7	19	2	1×10^{-5}
39	47	Ag^{111}	β⁻	Liver	1.7	39	5	3×10^{-6}
40	48	Cd^{109} + Ag^{109} [4]	γ, K	Liver	1.7	45	7×10^{-2}	7×10^{-8}
41	50	Sn^{113}	γ, K	Bone	7	84	0.2	6×10^{-7}
42	52	Te^{127}	β⁻, γ	Kidneys	0.3	4	3×10^{-2}	1×10^{-7}
43	52	Te^{129}	β⁻, γ	Kidneys	0.3	1.4	1×10^{-2}	4×10^{-8}
44	53	I^{131}	β⁻, γ	Thyroid	0.02	0.6	6×10^{-5}	6×10^{-9}
45	54	Xe^{133}	β⁻, γ	Total body	70	320	4×10^{-3}	4×10^{-6}
46	54	Xe^{135}	β⁻, γ	Total body	70	100	1×10^{-3}	2×10^{-6}
47	55	Cs^{137} + Ba^{137} [4]	β⁻, γ	Muscle	30	98	2×10^{-3}	2×10^{-7}
48	56	Ba^{140} + La^{140} [4]	β⁻, γ	Bone	7	1	5×10^{-4}	2×10^{-8}

	Radioisotope		Critical Organ[1]		Maximum Permissible Total Body Burden[2]	Maximum Permissible Concentration	
	Z	Symbol A	Type of Decay	Organ	wt. kg		In H_2O	In Air
						μc	μc/ml	μc/ml
53	57	La^{140}	β⁻, γ	Bone	7	7	0.3	4×10^{-7}
54	58	Ce^{144} + Pr^{144} [4]	β⁻, γ	Bone	7	1	8×10^{-3}	2×10^{-9}
55	59	Pr^{143}	β⁻	Bone	7	6	8×10^{-2}	2×10^{-7}
56	61	Pm^{147}	β⁻	Bone	7	25	0.2	4×10^{-8}
57	62	Sm^{151}	β⁻	Bone	7	90	5×10^{-2}	3×10^{-9}
58	63	Eu^{154}	β⁻, γ	Bone	7	7	1×10^{-2}	2×10^{-9}
59	67	Ho^{166}	β⁻, γ	Bone	7	4	5	8×10^{-7}
60	69	Tm^{170}	β⁻, γ	Bone	7	4	6×10^{-2}	1×10^{-8}
61	71	Lu^{177}	β⁻, γ	Bone	7	18	6	1×10^{-6}
62	73	Ta^{182}	β⁻, γ	Liver	1.7	6	1×10^{-1}	2×10^{-8}
63	74	W^{181}	K, γ, e⁻	Bone	7	24	0.1	5×10^{-6}
64	75	Re^{183}	K, γ	Thyroid	0.02	37	9×10^{-2}	9×10^{-6}
65				Skin	2	650	0.3	3×10^{-5}
66	77	Ir^{190}	β⁻, γ	Kidneys	0.3	23	1×10^{-2}	8×10^{-7}
				Spleen	0.15	21	0.2	1×10^{-6}
68	77	Ir^{192}	β⁻, γ	Kidneys	0.3	3	9×10^{-4}	5×10^{-8}
				Spleen	0.15	3	6×10^{-3}	3×10^{-8}
70	78	Pt^{191}	K, γ	Kidneys	0.3	2	6×10^{-3}	2×10^{-7}
71	78	Pt^{193}	K, γ, e⁻	Kidneys	0.3	3	5×10^{-3}	2×10^{-7}
72	79	Au^{196}	K, β⁻, γ	Liver	1.7	8	5×10^{-2}	2×10^{-7}
				Kidneys	0.3	32	5×10^{-3}	2×10^{-7}
74	79	Au^{198}	β⁻, γ	Liver	1.7	3	4×10^{-2}	2×10^{-7}
				Kidneys	0.3	10	3×10^{-3}	1×10^{-7}
76	79	Au^{199}	β⁻, γ	Liver	1.7	9	9×10^{-2}	4×10^{-7}
				Kidneys	0.3	30	8×10^{-3}	3×10^{-7}
78	81	Tl^{200}	K, γ, e⁻	Muscle	30	40	2×10^{-2}	2×10^{-6}
79	81	Tl^{201}	K, γ	Muscle	30	310	8×10^{-2}	7×10^{-6}
80	81	Tl^{202}	K, γ, e⁻	Muscle	30	230	2×10^{-2}	2×10^{-6}
81	81	Tl^{204}	β⁻	Muscle	30	200	8×10^{-3}	7×10^{-7}
82	82	Pb^{203}	K, γ	Bone	7	61	0.1	7×10^{-6}
83	82	Pb^{210} + dr^{4}	α, β⁻, γ	Bone	7	0.2	2×10^{-6}	8×10^{-11}
84	84	Po^{210} (α,)	α, γ	Spleen	0.15	0.04	3×10^{-5}	5×10^{-10}
85	84	Po^{210} (i.)	α, γ	Lungs	1	0.02		1×10^{-10}
86	85	At^{211}	α, K	Thyroid	0.02	0.001	3×10^{-6}	5×10^{-10}
87	86	Rn^{220} + dr	α, β, γ	Lungs	1			1×10^{-7}
88	86	Rn^{222} + dr	α, β, γ	Lungs	1			1×10^{-7}
89	88	Ra^{226} + 55% dr [4]	α, β, γ	Bone	7	0.1	4×10^{-8}	8×10^{-12}
90	89	Ac^{227} + dr [4]	α, β, γ	Bone	7	0.01	3×10^{-6}	4×10^{-12}
91	90	Th-natural	α, β, γ	Bone	7	0.01	5×10^{-7}	3×10^{-11}
92	90	Th-natural (i.)	α, β, γ	Lungs	1	0.002		3×10^{-11}
93	90	Th^{234} + Pa^{234} [4]	β⁻, γ	Bone	7	2	5×10^{-2}	1×10^{-8}
94	92	U-natural (α,)	α, β⁻, γ	Kidneys	0.3	0.04	1×10^{-4}	3×10^{-10}
95	92	U-natural (i.)	α, β⁻, γ	Lungs	1	0.01		3×10^{-11}
96	92	U^{233} (α,)	α, γ	Bone	7	0.04	1.5×10^{-4}	3×10^{-11}
97	92	U^{233} (i.)	α, γ	Lungs	1	0.016		3×10^{-11}
98	94	Pu^{239} (α,)	α, γ	Bone	7	0.04	6×10^{-6}	2×10^{-12}
99	94	Pu^{239} (i.)	α, γ	Lungs	1	0.02		2×10^{-12}
100	95	Am^{241}	α, γ	Bone	7	0.06	2×10^{-4}	4×10^{-10}
101	96	Cm^{242}	α	Bone	7	0.06	1×10^{-3}	2×10^{-9}
102	Any fission mixture (β, γ)[5]						1×10^{-7}	1×10^{-9}
103	Any mixture of α-emitters[5]						1×10^{-10}	5×10^{-12}

/1/ Organ or tissue of body receiving the radioisotope that results in the greatest body damage. /2/ Exclusive of the amount in the gastrointestinal tract. /3/ Common body element. /4/ Values in μc and μc/ml given for parent element; daughter elements assumed to reach appropriate fraction of equilibrium with the parent after being taken into the body. /5/ Values for unidentified β-, γ-, and α-emitters for short periods of time (a few months). /6/ Safe for any mixture of β- and γ-emitters and all α-emitters except Ra^{226}. /7/ Safe for any mixture of β- and γ-emitters except Sr^{90} /8/ Safe for any mixture of α-emitters except Pu^{239} and Ac^{227}.

405. MAXIMUM PERMISSIBLE EXTERNAL EXPOSURE OF BODY ORGANS TO IONIZING RADIATIONS: MAN, ADULT[1]

Values may be converted from units of mrem/wk to mrad/wk by dividing by appropriate values of RBE (relative biological effectiveness). Commonly assumed average RBE values are: 1 for X, γ, β, e^- and e^+; 10 for p and α, and 20 for heavy ions (oxygen, carbon, nitrogen). Values in parentheses apply to persons over 45.

Mev = million electron volts; mr = millionth, mrad = millirad; mrem = millionth rem or equivalent, man or mammal; rad = unit of energy absorption.

	Type of Radiation	At Surface of Body Trunk	In Skin[2, 3]		In Eye Lenses[5] mrem/wk	In Gonads[5] mrem/wk	In Blood-forming Organs[5] mrem/wk	In Intermediate Tissue[3, 6] mrem/wk
			Total Body mrem/wk	Body Appendages[4] mrem/wk				
1	Low, penetrating[7]	1500 mrad/wk	1500	1500	300	300	300	300-1500
2		(1500 mrad/wk)	(1500)	(1500)	(600)	(600)	(600)	(600-1500)
3	Roentgen (X) and	450 mr/wk	450	1500	450	300	400	400-450
4	gamma (γ) of <3 Mev	(900 mr/wk)	(900)	(1500)	(600)	(800)	(800)	(800-900)
5	Electrons (β^-,	600 mrad/wk	600	1500	300	300	300	300-600
6	e^-, e^+)	(1200 mrad/wk)	(1200)	(1500)	(600)	(600)	(600)	(600-1200)
7	Protons (p)	60 mrad/wk	600	1500	300	300	300	300-600
8		(120 mrad/wk)	(1200)	(1500)	(300)	(600)	(600)	(600-1200)
9	Fast neutrons	30-2000 n/sq cm/sec	300-600[8]	750-1500[8]	300	300	300	300-600
10	(n_f)	(60-4000 n/sq cm/sec)	(600-1200)[8]	(750-1500)[8]	(300-600)[8]	(600)	(600)	(600-1200)
11	Thermal neutrons	3000 n/sq cm/sec	500[8]	1200[8]	300	100, 300[8, 9]	170[8]	170-500
12	(n_t)	(6000 n/sq cm/sec)	(1000)[8]	(1200)[8]	(420)[8]	(200, 600)[8, 9]	(340)[8]	(340-1000)
13	Alpha particles	Exposure from internally	1500	1500	300	300	300	300-1500
14	(α)	deposited isotopes	(1500)	(1500)	(300)	(600)	(600)	(600-1500)
15	Oxygen, carbon,	Generated in body by	1500	1500	300	300	300	300-1500
16	nitrogen, etc.	fast neutrons	(1500)	(1500)	(300)	(600)	(600)	(600-1500)

/1/ Further information concerning data in this table may be obtained from Subcommittee 1, "Permissible Dose from External Sources," and Subcommittee 2, "Permissible Internal Dose," National Committee on Radiological Protection; also from Handbooks 52 and 59, National Bureau of Standards. /2/ Minimum thickness of epidermis taken as 0.07 mm. /3/ Values must not be used unless radiation is shielded or localized so that exposure limits to other critical tissues are not exceeded. /4/ Appendages include head, neck, hands, forearms, feet, and ankles. /5/ Average depths of lens, ovaries, testes, and blood-forming organs considered to be 3 mm, 7 cm, 1 cm, and 5 cm respectively. /6/ "Intermediate" tissue considered to be that of body trunk 0.07 mm-5 cm in depth (excluding testes and lens of eye). /7/ Low penetrating radiation ($X, \gamma, \beta, e, \alpha$ or p) with a half-value layer of less than 1 mm of soft tissue; does not apply to neutron radiation. /8/ Values for neutron surface dose determined by pattern of distribution in body; values used decrease with energy of neutrons. /9/ Smaller value applies to ovaries at 7 cm depth, and larger value to testes at 1 cm depth.

406. BACKGROUND AND NON-OCCUPATIONAL EXPOSURES TO IONIZING RADIATION: MAN

β = beta ray; c = curie; μc = microcurie; r = roentgen; mr = millionth rem; mrep = millionth equivalent physical; μg = microgram; γ = gamma ray.

	Source	Amount or Rate
1	Air, radon (incl. thoron)	$\sim 10^{-10}$ μc/ml
	Airplane instruments (10-100 μg per dial)	
2	At face of each dial	5-10 mr/hr
3	At pilot's position	<1 mr/hr
4	"Background" exposure, average	0.4 mrep/da
5	natural[1]	0.01-0.1 mr/hr
6	C^{14} (isotopic abundance 1.6×10^{-12})	16 dis./min/g carbon[2]
	Cosmic rays	
7	Sea level	$\sim$0.1 mr/da
8	15,000 ft altitude	0.5 mr/da
9	55,000 ft altitude	7.5 mr/da
10	Top of atmosphere	70.0 mr/da
11	Cow's milk	10^{-14} c/ml
	Earth's outer crust	
12	Radium by weight	2×10^{-6}
13	Thorium by weight	12 ppm
14	Uranium by weight	6 ppm
	Human body	
15	C^{14}, total	0.0068 μc
16	K^{40}, total	0.12 μc
17	Residual activity, all A-bomb detonations[3] calculated to July 15, 1952	8.8×10^{6}c

	Source	Amount or Rate
18	Shoe fitting (20 sec exposure)	av. 10-15 r to feet
19	Spectacle lenses containing U	1-8 mr/hr β to eyes
20	Water, drinking	10^{-16}-10^{-12} c/ml
	Water, sea	
21	K^{40}	0.33 μc/cu m
22	U	0.0015 mg/kg
23	Watch dial, wrist ($\sim$1 μg Ra)	$\sim$1 mr/hr, γ, wrist
	X-ray, diagnostic[4]	
24	Abdomen[5]	1.3 r
25	Chest, photofluorographic	0.7-1.2 r
26	Chest, plate 14 x 17 in.	0.05-0.25 r
27	Dental	0.5 r/film
28	Extremities	0.25-1.0 r
29	Fluoroscopy	0.28 r/sec
30	Gastrointestinal series	0.65 r/plate
31	Lumbar spine, lateral[6]	5.7 r
32	Pelvimetry, central area, anterio-posterior films	0.2-0.4 r/film
33	Pregnancy, lateral	9.0 r
34	Skull	1.3 r?
35	Urographic series, center of abdomen	1.3 r

/1/ Approximate total of cosmic ray and natural "background" 0.3 mr/24 hr. /2/ 16 disintegrations per min/g carbon. /3/ Includes suspended and deposited particles. /4/ Considerable variation depending on filtration distance and techniques. /5/ Abdominal fluoroscopy plus spot and serial films; 3 r in center of abdomen (may be higher). /6/ Up to 8 r in center of abdomen. /7/ Considerable variation depending on scope and type of examination.

407. HEAVY IONIZING PARTICLES: RELATIVE BIOLOGICAL EFFECTIVENESS VALUES

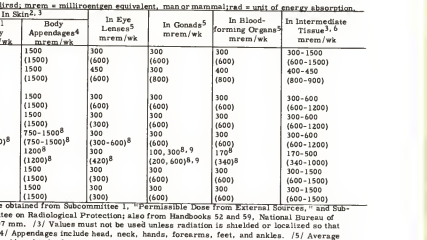
The following RBE values for all the critical organs, according to the value of the average specific ionizations (occurring in the critical organ in which it is highest) are recommended for determination of permissible tissue doses in rads from external sources by the relation: Permissible dose in rads = permissible dose in rems divided by RBE.[1]

	Average Specific Ionization ion pairs/μ2	RBE	Average Linear Energy Transfer to H_2O kev/μ
1	100 or less	1	3.5 or less
2	100-200	1-2	3.5-7
3	200-650	2-5	7-23
4	650-1500	5-10	23-53
5	1500-5000	10-20	53-175

/1/ International Commission on Radiological Protection (1955). /2/ i.e., μ of path of H_2O.

408. RADIOISOTOPES, BODY ABSORPTION HAZARDS: MAN

These selected radioisotopes are grouped according to relative radiotoxicity, with the amounts considered as low, intermediate, or high level, in laboratory practice. The slant boundaries between levels indicate borderline zones and emphasize that there is no sharp transition between the levels and the associated protection techniques. This activity scale system does not apply to the hazards of external radiation.



Data are approximate exposures for various biological effects. Exposure required for a specific test may vary with such biological factors as species, age, metabolic state, and with certain physical factors including temperature and oxygen tension.

α = alpha rays; β = beta rays; γ = gamma rays; n = n unit[1]; x = roentgen - or X-rays

	Exposure Level[2]				Test Period[3]	Test Material	Effect Observed
	x	γ	α	β	n			
1	8					24 hr	Grasshopper (neuroblast)	Reduced rate of mitosis.
2	15-500					10 da	Frog (sperm)	Abnormal development (5-100%).
3	20-600	20-600				1-28 da	Mouse (testis)	Damage to germinal cells.
4	30-800					5 da	Mouse (thymus)	Weight loss.
5	35-225					2 hr-4 da	Mouse (skin)	Cells in mitosis decreased.
6		36-540			6-150	1.5-48 hr	Rat (retina)	Inhibition of mitosis.
7	50					10 min	Carboxypeptidase (dilute)	30% inactivation.
8	50					12 da	Salamander (eggs)	LD_{50}.
9	50					21 da	Grasshopper (eggs, 6 da old)	LD_{50} (or abnormal development, 50%).
10	50-110					18 hr	Bluebottle fly (eggs)	LD_{50}.
11	100					24 hr	Chick (fibroblast culture)	Death of cells at next division.
12	100-600					3-10 da	Mouse (blood)	Decreased number of cells.
13	100-1000					7 da	Frog (eggs, fertilized)	Inhibition or abnormality of development.
14	125					21 da	Grasshopper (eggs, 1 da old)	LD_{50} (or abnormal development, 50%).
15	140	250	36			1-14 da	Broad bean (root)	Inhibition of growth (cell division).
16	175-250	310		7750		14 da	Guinea pig[4]	LD_{50}.
17	190	240		275	85	48 hr	Fruit fly (eggs)	LD_{50} (failure to hatch).
18	200					24 hr	Thymus (cell suspension)	Death of cells (eosin staining).
19	300-350					30 da	Dog	LD_{50}.
20	320					5 da	Tradescantia (microspores)	Chromosome breaks (17.3%).
21	350					30 da	Goat	LD_{50}.
22	350					2 wk	Fruit fly (adult)	1% increase in sex-linked mutations.
23		375-3600				2 wk	Fruit fly	Increased recessive mutation rate.
24	400[5]					30 da	Man	LD_{50} (estimated).
25	400					24 hr	Spleen (cell suspension)	Death of cells (eosin staining).
26	400					15 da	Chick embryo (50 hr incubation)	Death of embryo.
27	400-500[6]					30 da	Swine	LD_{50}.
28	400-600[7]	850-950		4700	200-400	30 da	Mouse	LD_{50}.
29	500					100 hr	Wheat seedling (root, 18 hr old)	50% decrease in growth rate (longitudinal).
30	500					30 da	Monkey	LD_{50}.
31	600-900	1270		7500	200-300	30 da	Rat	LD_{50}.
32	670					30 da	Goldfish	LD_{50}.
33	700					6 wk	Frog	LD_{50}.
34	725[8]					30 da	Hamster	LD_{50}.
35	800				175-400	30 da	Rabbit	LD_{50}.
36	800[9]					12 da	Chicken	LD_{50}.
37	1000					4 da	Ascaris (eggs)	LD_{50}.
38	1000					3 wk	Duckweed	50% decrease in growth rate of fronds.
39	1000-2000					100 hr	Tomato, lettuce (germinated)	Inhibition of linear growth of shoot.
40	1000-2000					1 yr	Pigeon (<15 da old)	Inhibition of growth of wing bone.
41	1100					70 hr	Wheat seedling (primary leaf)	50% decrease in growth rate (longitudinal).
42	1500					30 da	Turtle	LD_{50} (estimated).
43	2000					1 wk	Fundulus (eggs, gametes, embryo)	Abnormal development of embryo.
44	2500					100 da	Salpiglossis	50% decrease in growth rate; repression of flowering.
45	2,500-10,000					3 hr	Chick (fibroblast culture)	Immediate death of cells.
46	3000					30 da	Triton (salamander)	LD_{50} (estimated).
47	3,000-50,000					2 wk	Neurospora (ascospores)	Production of biochemical mutants.
48	5,000-60,000					10 da	Mouse sarcoma 180	Inhibition of growth in transplants.
49	5600				2500	24 hr	Escherichia coli	LD_{50}.
50	10,000-100,000					10-40 da	Trypanosoma cruzi	Decreased infective power.
51	10,000-120,000					3-10 da	Tobacco callus (tissue culture)	Inhibition of growth.
52	15,000					32 da	Rabbit (mesenteric lymph node)	Inhibition of cell migration.
53	30,000					2 hr	Arbacia (eggs)	Delay of cleavage.
54	30,000					1 hr	Yeast cells	Immediate death.
55	40,000					5 hr	Frog (sperm)	Incomplete inactivation.[10]
56	50,000					24 hr	Rhizopus nigricans (spores)	50% less germination than controls.
57	94,000					3 wk	Chaetomium globosum (spores)	Lethal mutants in 50%.
58	100,000					10 min	Carboxypeptidase (concentrated)	30% inactivation.
59	150,000				37,000	24 hr	Bacillus mesentericus (spores)	LD_{50}.
60	180,000					30 hr	Penicillium (spores)	50% less germination than control.
61	200,000					40 da	Grasshopper embryo	Depression of respiration.
62	200,000					18 hr	Escherichia coli (phage C36)	37% inactivation.
63	210,000					18 hr	Lily (pollen grains)	50% less germination than control.
64	300,000-600,000					45 min	Pandorina	Immediate death.
65	330,000					2 hr	Colpidium colpoda	LD_{50}.
66	350,000					10-15 min	Paramecium caudatum	Immediate loss of motility.
67	430,000	370,000	3900			5 da	Tobacco mosaic virus	37% inactivation.

/1/ One n unit = quantity of fast neutron radiation that will discharge a particular Victoreen ionizing chamber in the same magnitude as will one r of X-rays. Measurements have indicated that one n unit is approximately equivalent to 2.5 rep. /2/ Exposure levels for x- or gamma (γ) radiation in r (roentgens); all other exposures in rep (roentgen equivalent physical). /3/ Test period = time after irradiation when effect was observed. /4/ Hybrids are more radio-resistant. /5/ Whole body, hard X-rays. However, detectable biological changes occur at levels of 25-35r. /6/ LD_{50} also reported as 400-450r. /7/ LD_{50} also reported as about 625r, with range of 400-700r. /8/ LD_{50} also reported as 800r. /9/ LD_{50} for 30-da exposure for chicken depends upon age, but is estimated at 800-1000r. /10/ Sperm in testes can be used to fertilize eggs, even after testes have been exposed to 120,000r.

d = deuterons; e = electrons; n = neutrons; r = roentgens; α = alpha particles; β = beta particles; γ = gamma rays

	Material	Radiation	Dose	Intensity	Effect or Product	Molecules/100 ev
			Acids			
1	$C_nH_{2n+1}COOH$ (n = 1-29)	α (Rn)			CO_2.	0.5-2.8
2					CO.	<0.5
3					H_2.	<0.4
4					H_2O.	0.9-2.5
5					$C_n H_{2n+2}$.	0.4-1.1
6	Formic (aqueous)	e (1.4 Mev)			Loss of acid function.	2.5
7		d (4 Mev)			Loss of acid function.	1.7
8		γ (Co^{60})		5×10^4 r/hr	CO_2.	4.1
9					H_2.	0.5
10					H_2O_2.	4.6
11	Acetic (aqueous, deaerated, 1 M)[2]	He^{++} (35 Mev)[3]	3.8×10^{20} ev/ml	0.2 μa	CO_2.	0.28
12					Succinic acid.	0.32
13					CH_4.	0.08
14		d (18 Mev)	3.8×10^{20} ev/ml	0.2 μa	CO_2.	0.39
15					Succinic acid.	0.59
16					CH_4.	0.11
17	Caprylic (liquid)	α (Rn)			H_2. CO_2. CO. H_2O. CH_4. C_2H_6. C_3H_8. C_4H_{10}.	
18	Lauric (solid)	α (Rn)			H_2. CO_2. CO. H_2O. n-$C_{11}H_{24}$.	
19	Palmitic (solid)	α (Rn)			H_2. CO_2. CO. H_2O. n-$C_{15}H_{32}$.	
20	Glycolic, Ca salt (solid)	β (C^{14})	$1.75-2.54 \times 10^7$ r		Decomposition.	31-77
21	Oxalic (aqueous)	X (2.5 Mev)	$\sim 10^6$ r		Loss of acid function.	4-6
22	Lactic (aqueous)	X	1.2×10^6 r		Pyruvic acid.	
23	Benzoic (aqueous)	X (220 kv)	10^4-10^5 r	2350 r/min	o-$C_6H_4(OH)$ $COOH$.	1.0
24					m-$C_6H_4(OH)$ $COOH$.	
25					p-$C_6H_4(OH)$ $COOH$.	
			Alcohols, Thiols			
26	Methanol (liquid)	β (C^{14})	5.94×10^8 r		Decomposition.	12
27		He^{++} (27 Mev)[3]		$1.9-3.9 \times 10^{21}$ ev/sec	H_2.	3.4-4.1
28		He^{++} (27 Mev)[3]		$1.9-3.9 \times 10^{21}$ ev/sec	HCHO.	1.7
29	Ethanol (liquid)	He^{++} (27 Mev)[3]		$1.3-5.1 \times 10^{21}$ ev/sec	H_2.	1.8-3.2
30					CH_3CHO.	0.7-1.7
31					$(CH_3CHO)_2$.	0.7-1.1
32	Sucrose (solid)	X			Inversion, red color.	
33	Sucrose (aqueous)	X			Inversion.	
34	Propane-1, 3-dithiol (aqueous)	X (250 kv)	500-5000 r		Oxidation.	11
35	2,3-Dimercapto-1-propanol (BAL)(liquid)	X (250 kv)	500-5000 r		Oxidation.	11
			Vitamins and Related Compounds			
36	o-Aminobenzoic acid (aqueous)	e (3 Mev)			Decarboxylation, loss of amine function.	
37	β-Aminobenzoic acid (aqueous)	e (3 Mev)			Decarboxylation, loss of amine function.	
38	β-Carotene (petroleum ether)	X (3 Mev)	0.66×10^6 r		Decomposition.	0.16
39	Choline chloride (solid)	β (C^{14})	1.07×10^7 r		Decomposition.	490
40	Niacin (aqueous)	e (3 Mev)	0.17-5.28 x 10^6 r		Decarboxylation.	1.6
			Amino Acids			
41	Glycine (aqueous)	X (200 kv)		3500 r/min	H_2. NH_3. HCHO (trace).	Non-linear
42		X (500 kv)	1.66×10^5 r		NH_3.	~ 1
43		β (n α) Li	8-20 x 10^{20} ev/ml		NH_3.	$\lesssim 1.7$
44	Alanine (aqueous)	X (220 kv)		3500 r/min	H_2. NH_3. CH_3CHO (trace).	Non-linear
45	Serine (aqueous)	X (200 kv)		3500 r/min	H_2. NH_3. $(CHO)_2$. $HOCH_2CHO$.	Non-linear
46	L-Serine (aqueous)	X	1.66×10^5 r		NH_3.	1-13
47	Valine. HCl (solid)	β (C^{14})	8.2×10^5 r		Decomposition.	0.3
48	Norvaline. HCl (solid)	β (C^{14})	4.03×10^7 r		Decomposition.	1.7
49	Norleucine (solid)	β (C^{14})	3.2×10^6 r		Decomposition.	10
50	Cysteine (aqueous)	X (250 kv)		10^3 r/min	Loss of thiol function.	6-26
51					H_2O_2.	0-7
52					H_2S.	~ 1 (aerated)
53					H_2S.	2.5-5 (deaerated)
54	Histidine. HCl (aqueous)	e (3 Mev)	10^5 - 10^6 r		Decomposition.	1.0-10
			Steroids			
55	Cholesterol (aqueous)	X (200 kv)		3000 r/min	Cholestane-3(β), 5(α), 6(β)-triol; 3(β)-hydroxycholest-5-en-7-one.	
56	Δ 5-Pregnen-3-(β)-ol-20-one (aqueous)	X (200 kv)		3000 r/min	3(β),5(α), 6(β)-Trihydroxyallopregnan-20-one.	
57	Cholic acid (aqueous)	X (220 kv)	1.8×10^6 r		3(α), 12(α)-Dihydroxy-7-ketocholanic acid. A lactone.	
58	(+)-Estrone-b (aqueous)	X (200 kv)	10^6 r			
			Miscellaneous			
59	Desoxyribonucleic acid (aqueous)	X (200 kv)		3000 r/min	NH_3.	0.4
60					Inorganic phosphate.	0.003
61	Yeast ribonucleic acid (aqueous)	X (200 kv)		3000 r/min	NH_3.	0.4
62					Inorganic phosphate.	0.01
63	Sodium thymonucleate (aqueous)	X (0.2, 2 Mev)			Decomposition.	
64		γ (Ra, Co^{60})			Decomposition.	
65	Carboxypeptidase (aqueous)	α (Rn)			Inactivation.	~0.06
66		X (500 kv)			Inactivation.	0.03
67	Ferricytochrome c (aqueous)	X (180-200 kv)			Inactivation.	0.55
68	Glutathione (aqueous)	X (250 kv)	500-5000 r	439-1700 r/min	Oxidation.	1.7
					Oxidation.	10

/1/ In all aqueous media radiolysis may yield H_2, H_2O_2, and O_2; dependent on conditions; such data are not included here. /2/ Data for aerated solution are more complex. /3/ Rays of artificial (cyclotron) origin.

411. ULTRAVIOLET RADIATION EFFECTS: BIOLOGICALLY IMPORTANT COMPOUNDS

	Substance[1]	Irradiation	Products or Results of Irradiation	Quantum Efficiency moles/Einstein[2]
			Amino Acids and Amines	
1	L-Alanine	Hg-lamp	L-Lactic acid, pyruvic acid, NH_3.	0.027
2	Aminoisobutyric acid	Hg-lamp	NH_3 + (?).	
3	L-Aspartic acid	Hg-lamp	L-Malic acid.	
4	Betaine	Hg-lamp	Trimethylamine.	0.02
5	Cysteine	Hg-lamp	Cystine + (?).	
6	Cystine	2250Å	Cysteine + (?).	0.02
7	Dihydroxyphenylalanine (dopa)	Hg-lamp	Unknown.	
8	Glycine	2265Å	Glycolic acid, NH_3, CO.	0.033
9	Histamine	Hg-lamp	Unknown.	
10	Histidine		Imidazol-acetaldehyde, NH_3, hydroxy acid, histamine (?).	
11	Homocystine	Hg-lamp	S-Benzylhomocysteine.	
12	Leucine	Hg-lamp	NH_3 + (?).	
13	Methionine	2250Å	Methylmercaptan.	
14	Phenylalanine	Hg-lamp	NH_3, modified phenyl group, tyrosine.	
15	Proline, hydroxyproline	Hg-lamp	Destruction.	
16	Tryptophan	Hg-lamp	Indole-3-acetic acid + (?); change in absorption spectrum.	
17	Tyrosine	Hg-lamp	Unknown; some dopa; change in absorption spectrum.	
18	Valine	Hg-lamp	NH_3 + (?).	
			Hemipeptides[3]	
19	Acetylalanine	2537Å	NH_3 + (?).	0.072
20	Acetyltryptophan	2537Å	Modified indole group; no tryptophan.	
21	Benzoylalanine	2537Å	Alanine, modified phenyl group.	0.0027
22	Benzylsterarylamine	2483Å, 2537Å	Stearic acid, benzylamine.	
23	Phenylacetylalanine	2537Å	Alanine, modified phenyl group.	0.0064
24	Phenylbutyrylalanine	2537Å	Alanine, modified phenyl group.	0.055
25	β-Phenylethylsterarylamine	2483Å, 2537Å	Stearic acid, β-phenylethylamine.	
26	Phenylpropionylalanine	2537Å	Alanine, modified phenyl group.	0.0041
27	Phenylvalerylalanine	2537Å	Alanine, modified phenyl group.	0.0034
28	Propionylphenylalanine	2537Å	NH_3, modified phenyl group.	0.005
29	Stearic anilide	2350Å, 2400Å	Stearic acid, aniline.	0.26
			Peptides	
30	Acetylalanylglycine	Hg-lamp	NH_3 + (?).	
31	Alanylglycine	Hg-lamp	NH_3 + (?).	
32	Glycylleucine	Hg-lamp	NH_3 + (?).	
33	Glycyltryptophan		Modified indole group; no amino acids.	
34	Glycyltyrosine	2537Å	Modified phenyl group; no amino acids.	
35	Gramicidin		Destruction.	0.0034
36	Leucyltyrosine		Modified phenyl group; no amino acids.	
			Purines and Derivatives	
37	Adenine	2537Å	NH_3, urea; loss of characteristic absorption spectrum.	
38	Adenosine	2537Å	NH_3, urea; loss of characteristic absorption spectrum.	
39	Adenosinetriphosphate	<3000	Adenine.	
40	Adenylic acid	2537Å	NH_3, urea; pentose destruction; loss of characteristic absorption spectrum.	
41	Diphosphopyridine nucleotide(DPN)	<3000	Adenine; adenylic acid, adenosine diphosphate, nicotinamide; loss of coenzyme function.	
42	Triphosphopyridine nucleotide(TPN)	2537	Adenosine 2',5'-diphosphate, 2'-phospho-adenosine diphosphate, nicotinamide.	
43	Guanine, guanosine, guanylic acid, hypoxanthine, inosine, uric acid, xanthine, xanthosine	2537Å	NH_3, urea; loss of characteristic absorption spectra; uric acid also yields triuret.	
			Pyrimidines and Derivatives	
44	Cytidine	2537Å	NH_3, urea; loss of characteristic absorption spectrum; pentose of cytidylic acid destroyed.	
45	Cytidylic acid			
46	Cytosine		6- or 5-Hydroxy-1, 3-dimethylhydrouracil.	
47	1, 3-Dimethyluracil		NH_3, urea; loss of characteristic absorption spectrum.	
48	Thymine		Adenine; adenylic acid, adenosine diphosphate, nicotinamide; loss of coenzyme function.	
49	Uracil	2537Å	NH_3, urea; loss of characteristic absorption spectrum. (Primary product reverts to uracil in acid. Change in absorption spectrum, oxamide and parabanic acid.)	
50	Uridine		NH_3, urea; loss of characteristic absorption spectrum. (Primary product reverts to uridine in acid.)	
51	Uridylic acid		Unknown product which reverts to uridylic acid in acid solution.	0.0216
			Nucleic Acids	
52	Desoxyribonucleic acid	2537Å	Depolymerization and destruction of pyrimidine bases; loss of characteristic absorption spectrum and liberation of inorganic phosphate.	10^{-6}(depolymerization)
53	Desoxyribonucleic acid	2650Å	Gel formation.	0.01-0.04(dry)
54	DNA (transforming principle)		Inactivated by 500 ergs/sq mm per 200 μg DNA.	
55	Ribonucleic acid	2537Å	Depolymerization; loss of characteristic absorption spectrum.	0.1 (depolymerization)
			Vitamins	
56	B_1 (2-methyl-5-ethoxymethyl-6-aminopyrimidine component)	2537Å	Loss of selective absorption and ability to support growth of Phycomyces blakesleeanus.	0.184
57	B_1 (4-methyl-5-β-hydroxyethyl-thiazole component)	2537Å	Loss of ability to support growth of Phycomyces; changes in side groups, breakdown of ring.	0.347
58	Ergosterol	2536Å, 2800Å	Vitamin D_2	0.2-0.3
			Enzymes and Related Proteins[3]	
59	Aldolase	2537Å	Loss of hexose diphosphate activity.	0.0019
60	Antibody, bushy stunt virus			0.00096
61	Antibody, clover nodule bacteria		Reduction in flocculation of antigen.	0.0024
62	Antibody, tobacco mosaic virus			0.00096
63	Carboxypeptidase		Loss of chloroacetyltyrosinase activity.	0.001
64	Catalase		Loss of hydrogen peroxidase activity.	0.0011(dry)

/1/ In aqueous solution, unless otherwise indicated. /2/ Equivalent to number of molecules reacting per number of quanta absorbed. /3/ Values are representative and usually vary with pH. Absolute value depends on assumed molecular weight.

411. ULTRAVIOLET RADIATION EFFECTS: BIOLOGICALLY IMPORTANT COMPOUNDS (Concluded)

	Substance[1]	Irradiation	Products or Results of Irradiation	Quantum Efficiency moles/Einstein[2]
			Enzymes and Related Proteins[3] (concluded)	
65	Chymotrypsin	2537 Å	Loss of activity on casein.	0.0065
66	Chymotrypsin	2967 Å - 2301 Å		0.008-0.002(dry)
67	Chymotrypsinogen		Inability to convert to chymotrypsin.	0.011(dry)
68	Desoxyribonuclease		Loss of nuclease activity.	0.0039(dry)
69	Insulin		Inability to produce hypoglycemic convulsions in mice.	0.015
70	Lysozyme		Loss of Micrococcus lysedeikticus activity.	0.24
71	Pancreatic trypsin inhibitor		Loss of trypsin-inhibiting power.	0.031
72	Pepsin	2537 Å	Loss of hemoglobinase activity.	0.0024
73	Ribonuclease		Loss of nuclease activity.	0.03
74	Triosephosphate dehydrogenase		Loss of effect on diphosphopyridine nucleotide.	0.003
75	Trypsin			0.018
76	Trypsin		Loss of caseinase activity.	0.02-0.1(dry, 90°-450°K)
77	Trypsin inibitor, soybean		Loss of trypsin-inhibiting activity.	0.0088
78	Urease	1860 Å		0.00938
79	Urease	2537 Å	Loss of urease activity	0.00093
80	Urease	3130 Å		0.00816
			Viruses and Phages[3]	
81	Tobacco mosaic virus	2537 Å	Virus sensitized to heat, suffers loss of infectivity for Nicotiana glutinosa.	4.3×10^{-5}
82	T_1 phage	2220 Å		5.0×10^{-4}
83	T_1 phage	2537 Å		6.3×10^{-4}
84	T_1 phage	3022 Å	Loss of activity on Escherichia coli, strain B.	7.3×10^{-4}
85	T_2 phage	2220 Å		2.7×10^{-4}
86	T_2 phage	2537 Å		3.1×10^{-4}
87	T_2 phage	3022 Å		1.8×10^{-4}

/1/ In aqueous solution, unless otherwise indicated. /2/ Equivalent to number of molecules reacting per number of quanta absorbed. /3/ Values are representative and usually vary with pH. Absolute value depends on assumed molecular weight.

412. ULTRAVIOLET RADIATION: LD_{50} FOR SOME UNICELLULAR ORGANISMS

Values in parentheses are ultraviolet wave lengths in $m\mu$.

	Organism	Ultraviolet Wave Length, $m\mu$								
		(310)	(302)	(297)	(290)	(280)	(265)	(254)	(248)	Other
		LD_{50} Dose, ergs/sq mm								
	Bacteria[2]									
1	Escherichia coli	4580		2965	339	181-225	104	44-208		172(270)
2	Micrococcus candicans		11,375	3775		295	212	341		
3	Pseudomonas pyocyanea			7150		320	234	291		
4	Staphylococcus aureus		3000	500	200	110-440	90-206	86-275	96	150(238)
5	Serratia marcescens			677		47	49	57		73(240)
6	Salmonella typhi-murium	5556				237				
	Fungi									
7	Saccharomyces cerevisiae, in dark		23,500			556-1260	457-863	503-900	696	1156(238)
8	in light							1400		
	Neurospora crassa, microconidia,									
9	in dark		1050			496	300	370		585(238)
10	in light							1020		
	Neurospora crassa, macroconidia,									
11	in dark					1700	1120	1440		
12	in light							3000		
	Protozoa									
13	Amoeba proteus, in dark							2160		
	Paramecium aurelia,									
14	in dark					3000				
15	in light					6000				
	Protophyta									
16	Chlorella pyrenoidosa, in dark							30,000		

/1/ Sterilizing dose, or dose which prevents colony formation under the usual conditions for culture of the organism. /2/ Not specified whether bacteria were handled in the light or dark.

Ranges, when preceded by average values, are given in parentheses.

c = curie; mc = millicurie; μc = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit[1]; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; α = alpha rays; γ = gamma rays.

	Radiation		Latent Period	Late Effects
	Type	Amount		
			Man	
1	A-bomb	Epilation dose	2 yr	10 cases of A-bomb cataract Japan, 1 case USA.
2	Hiroshima	Irradiated in utero, 1st half of pregnancy	5 yr	Microcephaly and mental retardation were present in 7 of 11 children within 1200 m of hypocenter.
3	Japan	Area within 2000 m of hypocenter	3-5 yr	Leukemia incidence 9.3 times that of non-exposed population of Hiroshima and Nagaski (only 1948-50 incl.).
4		Area within 1000 m of hypocenter	3-5 yr	Leukemia incidence 32 times that of non-exposed population (only 1948-50 incl.).
5	Cyclotron	Epilation dose	2 yr	2 cases of cyclotron-induced cataract.
6	16 Mev neutrons, fast	400-500 n	2 mo-5 yr	Severe epidermolytic reaction (13/16), skin atrophy and fibrosis, persistent ulcerations, and diminished repair by normal tissues; radiation osteitis; severe bowel reactions.
7	0-20 Mev neutrons, fast (small γ components)	10-135 n	2-10 yr	Cataracts: severe(3/10), slight to moderate(4/10), minimal (3/10); chronic irradiation: no blood changes; 2 cases mild epilation.
8	Radium-226 (external)	1000-1500 mg-hr		Cessation of ovarian function, 77% (63/82).
9		1500-2000 mg-hr		Cessation of ovarian function (6/7).
10	Radium[2]	0.02-0.5 μg	14-48 yr	Radiation osteitis (2/5%).
11		0.5-2.0 μg	23.6 yr (1-32) yr	Osteomyelitis and loss of teeth (5/9); radiation osteitis (8/9); pathol. fractures (3/9); giant cell tumor (1/9); osteogenic sarcoma (1/9); epidermoid carcinoma nasopharynx (1/9); high incidence of deafness and arthritis.
12		2.7 μg	24.6 (8-32) yr	Osteomyelitis of jaw and loss of teeth (5/9); radiation osteitis (8/9), pathol. fracture (1/9); fibrosarcoma (1/9); epidermoid carcinoma nasopharynx (1/9).
13		2-20 μg residual (ingested)	6-8 yr	Radiation osteitis (osteosclerosis); osteogenic sarcoma (5/18 deaths); pathological fractures.
14		8-23 μg	19.5 (7-21) yr	Osteomyelitis of jaw and loss of teeth (6/8); radiation osteitis (7/8); epidermoid carcinoma nasopharynx (1/8); osteogenic carcinoma (1/8); pathol. fractures (3/8); leukemia (1/8).
15		10-180 μg	1-8 yr	Anemia with hyperplastic marrow, jaw necrosis (13 cases).
16		100-800 μg orig. dose, 1.0-10 μg residual radium	20-30 yr post treatment	Changes in bone density, similar to those in dead or dying bone, in all patients having at least 1 μg residual Ra; minimal changes with 0.5 μg (24 cases); dental changes in all with at least 4 μg residual Ra. Greatly enlarged haversian canals; distortion of normal bone configuration (7/24), edentia, mandibular lesions (3/19), aseptic necrosis of bone (7/24), fibrosarcoma, honey-combed teeth, "pink tooth."
17	Uranium, radium ores	Variable doses	13-23 yr	Lung cancer in uranium miners of Joachimsthal and Schneeberg.
18	X-ray	Variable doses	months to years	Skin atrophy, telangiectasis, sclerosis, pigmentation, alopecia and altered vasomotion, diminished sweat and sebaceous function; loss of cutaneous ridges and finger prints; ulcers and keratoses; malignancies; hyperkeratotic, warty growths; deformed and brittle, dry nails, loss of nails, fissures, subungual hyperkeratoses.
19		100-300 r (200 and 1000 kv)	60-680 da	Temporary drop in white blood cell count.
20		500-624 hr	100-600 da	Temporary macrocytic anemia.
21		625 r (to ovaries)		94% castrated.
22		≤ 1000 r (to center of vertebrae)	Followed 13 yr post-treatment	Permanent cessation of menstruation, 72 patients.
23		1000-2000 r (to spine)	Followed 3-7 yr	Vertebrae normal (irrespective of child's age); determined on 45 individuals, 34 living patients, 11 at autopsy.
24		1500-8500 r, therapeutic dose, eye tumor	2 yr	"Transverse-line" growth disturbance of vertebrae (irrespective of child's age up to 6 yr).
25		1500-25,000 r (130-200 kv)	6-22 yr	7 cases of cataract.
26		1700-3000 r (half value layer 1.5 mm Cu), lower abdomen	6-18 mo	11 cases osteogenic sarcoma.
27		About 2000 r (to spine)	Followed 2-13 yr	Nephrosclerosis; hypertension; elevated albuminuria (22/55); edema; anuria. Death from congestive heart failure and/or uremia (7/55); (over 2300 r there is high risk of renal failure).
28		3500-5000 r	8-28 mo	Contour irregularity of vertebrae (all children, except one 1 yr old).
29	X-ray, radium	4000-6700 r	8.6 (5-20) yr	Lens opacities (4 cases).
30	X-ray and radium equipment	Unknown		Sarcoma; osteogenic sarcoma. Therapy for lupus vulgaris, papillomata of bladder, actinomycosis, tubercular psoriasis.
				Leukemia in radiologists (4.68%). 9 times the incidence in non-radiological physicians (0.51%).

[1] One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one γ of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. [2] Variable amounts of mesothorium also present with the radium in some instances.

Ranges, when preceded by average values, are given in parentheses.
c = curie; mc = millicurie; μc = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit[1]; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; a = alpha rays; γ = gamma rays.

	Radiation			
	Type	Amount	Latent Period	Late Effects
			Dog	
31	Neutrons	0.012, 0.05, 0.11 n/day	1 yr	Reduction of lymphocytes only observed effect (6 doses/wk).
32		1.7 n/da	1 yr	Mucoid conjunctivitis, keratoconjunctivitis and corneal opacities; reduced size of spleen and testes; increased incidence of infection; hypoplasia of bone marrow and regional lymph nodes; hemorrhage of lymph nodes, heart, stomach, small bowel and kidney; reduction of lymphocytes, neutrophils and erythrocytes.
33	Neutrons, fast	150 n	2 yr	Destruction and chronic inflammation of cornea and changes in lens capsules and fibers, but no cataracts.
34		800-900 n	2 yr	Cataracts in 65-75% of animals.
35	X-ray	0.1 r/da (6 times/wk)	2 yr	Lowered sperm count, increase in abnormal sperm.
36		0.5 r/da	11 mo	Lowered sperm count, increase in abnormal sperm.
37		0.5 r/da	2 yr	Partial testicular atrophy; slight reduction of leucocytes;
38		1.0 r/da	6 mo	Lymphopenia.
39		1.0 r/da	9 mo	50% aspermic.
40		1.0 r/da	1 yr	100% aspermic; neutrophil dec.
41		1.0 r/da	2 yr	Severe injury of testes.
42		3.0 r/da	2 mo	Lymphocyte and platelet reduction.
43		6.0 r/da	9 mo	50% aspermic.
44		6.0 r/da	1.5 yr	Severe injury of testes.
45		10.0 r/da	2 mo	Lymphocyte, platelet, and erythrocyte depression.
46		10.0 r/da	3.5 mo	50% aspermic.
47		10.0 r/da	1.5 yr	Bone marrow hypoplasia; focal bowel and lymph node hemorrhages.
48		10.0 r/da	6 mo	50% survival.
			Guinea Pig	
49	Cobalt-60 (γ-rays), external	15 r/da	106 da	50% survival.
50		30 r/da	63 da	50% survival.
51		60 r/da	41 da	50% survival.
52		90 r/da	20 da	50% survival.
53		120 r/da	18 da	50% survival.
54	Phosphorus-32	7750 rep (external)	2 mo	Alopecia.
55	Radium, filtered (γ-rays), repeated low dose	Non-radiated (controls)	38 mo	75% survival.
56		0.11 r/da	38 mo	75% survival.
57		1.1 r/da (1050 r)	32 mo	50% survival.
58		2.2 r/da (2100 r)	32 mo	50% survival.
59		4.4 r/da (2400 r)	18 mo	50% survival; reduction white blood cells.
60		8.8 r/da (2300 r)	5 mo	50% survival; recurrent anemia.
			Mouse	
61	Cobalt-60 (γ-rays), external	90 r/da	52 da	50% survival.
62		115 r/da	37 da	50% survival.
63		140 r/da	22 da	50% survival.
64	Neutrons, fast, 10^3 ev to 2.4 Mev, and γ-rays (divided doses)	Non-radiated (contrds)	51 wk	50% survival for controls and each dosage increment. With respect to shortening life span, 1 n (divided small doses) is equivalent to 15 r. (For acute killing 1 n is equivalent to 9 r). Threshold for shortening life span is about 1 r/da and less than 0.1 n.
65		1 r/da	61 wk	
66		8.6 r/da	48 wk	
67		Non-radiated (controls)	70 wk	
68		0.115 n/da (total 32.2 n)	40 wk	
69		1.15 n/da (total 241.5 n)	30 wk	
70		4.3 n/da (total 301 n)	10 wk	
71		13 n/da (total 273 n)	3 wk	
72	Neutrons, fast, and X-rays (single exposure)	Non-radiated (controls)	64 wk	50% survival for controls and each dosage increment. Terminal changes are generalized; atrophy and an increased incidence of mediastinal lymphonatosis.
73		500 r	58 wk	
74		700 r	39 wk	
75		26 n	52 wk	
76		50 n	48 wk	
77		78 n	42 wk	
78		90 n	6 wk	
79	Neutrons, thermal	51 rem	14 wk	Lens opacities, 92% at 22 wk[3].
80		98.6 rem	14 wk	Lens opacities, 91% at 18 wk[3].
81		477 rem	6 wk	Lens opacities, 100% at 11 wk[3].
82	Phosphorus-32	3000-4000 rep (external)	30 da	General epilation, skin atrophy, loss of ear tips, ulcerations, keratosis.
83		3000-4000 rep (external)	3-4 mo	Lens opacities (4000 r).
84		3000-4000 rep (external)	8 mo	Lens opacities (3000 r).
85		3000-4000 rep (external)	6-8 mo	Tumors; shortening of life span.
86	Plutonium-239	3.1-15.6 μc/kg (i.v.)	190-250 da	Osteogenic sarcoma.
87		> 6.1 μc/kg (i.v.)		Marked shortening of life span.
88	Radium-226	> 12 μc/kg (i.v.)	250-300 da	Increased osteogenic sarcoma.
89		> 50 μc/kg (0.6-4170 μc/kg, i.v.)		Marked shortening of life span; debilitation and increased incidence of infection.

/1/ One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one r of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. /3/ n/X-ray relative biological effectiveness (RBE) for production of opacities is 9 times the n/X-ray RBE for 30 da lethality.

Ranges, when preceded by average values, are given in parentheses.
c = curie; mc = millicurie; μc = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit[1]; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; α = alpha rays; γ = gamma rays.

	Radiation Type	Amount	Latent Period	Late Effects
		Mouse (concluded)		
90	Radium filtered (γ-rays),	Non-radiated (controls)		
91	repeated low dose	1.1 r/da (760 r)		50% survival for controls and each dosage increment;
92		2.2 r/da (1390 r)		increase in lymphatic leukemia, mammary and ovarian
93		4.4 r/da (2640 r)		carcinoma.
94		8.8 r/da (4400 r)		
	Strontium-89 (β-rays)			
95	Monthly injections	0.05 μc/g	500 da	
96		0.1 μc/g	425 da	
97		0.2 μc/g	350 da	
98		0.5 μc/g	220 da	Bone tumors begin to develop.
99		0.1 μc/g	160 da	
100	Single injection	2.5 μc/g	200 da	
101		5.0 μc/g	150 da	
102	Uranium-232	0.1-1.0 μc/kg (i.v.)	575 da	Osteogenic sarcoma (probably significant); used 0.1-
103		> 1.0 μc/kg (i.v.)	575 da	10.0 μc/kg.
104	Uranium-233	2.5 μc/kg (i.v.)	575 da	Osteogenic sarcoma (probably significant); used 0.1-100 μc/kg.
105		> 5 μc/kg (i.v.)	575 da	Osteogenic sarcoma.
106		> 53 μc/kg (i.v.)	575 da	Shortening of life span.
107	Uranium-238	> 3.6 x 10^{-3} μc/kg (i.v.)	575 da	Possibly significant increase in osteogenic sarcoma.
108	X-ray	25-200 r to fetus early in pregnancy (equivalent to 2-6 wk, human)	Until birth	At birth severe skeletal and other abnormalities, with clearly defined critical periods.
109		Irradiation of fetus late in pregnancy (equivalent to after 6 wk, human)	Until birth	Several weeks after birth: cataracts, hydrocephalus; behavior disturbances; skin lesions.
110		50 r (250 kv)	17 wk	Lens opacities, 92% at 22 wk[3]. →
111		200 r (250 kv)	14 wk	Lens opacities, 91% at 18 wk[3].
112		500 r (250 kv)	6 wk	Lens opacities, 100% at 11 wk[3].
113		400 r (single dose)	15-23 mo	Ovarian tumors 15 times that of controls.
114		600-1200 r (divided doses)	9-14 mo	Myelosis 8 times that of controls.
115		600-1200 r (divided doses)	6-12 mo	Mediastinal lymphosarcoma 7 times that of controls.
116		600 r (120 kv, 150 r alternate wks, to whole body)	420-580 da	Lymphomas (33/63).
117		600 r (120 kv, 150 r alternate wks, to whole body, mediastinum shielded)	118-525 da	No lymphomas.
118		1200 r (120 kv, 300 r alternate wks, to upper half of body)	324-365 da	Lymphomas (3/40).
119		1200 r (120 kv, 300 alternate wks, to alternate halves of body)	420-508 da	Lymphomas (3/37).
120		Non-radiated (controls)	526-570 da	Lymphomas (3/36).
		Rabbit		
121	Neutrons	0.012 n/da, 6 doses/wk	1 yr	No observed effects.
122		0.06 n/da, 6 doses/wk	1 yr	No observed effects.
123		0.11 n/da, 6 doses/wk	1 yr	No observed effects.
124		1.7 n/da	1 yr	Increased incidence of infection; hypoplasia of bone marrow; atrophy of testes; reduction of lymphocytes; neutrophils depressed after 2 wk; erythrocytes after 32-35 wk.
125		3.7 n/wk (52.7-83.7 n, total)	4-12 mo	No lens changes.
126		33-100 n (single doses)	2-5 mo	Cataracts of posterior lens.
127	Fission	3 x 10^{10} particles/ml	125 da	Cataracts. } 2 x 10^9 particles/ml (or less) is
128	14 Mev	8 x 10^9 particles/ml	125 da	Cataracts. } threshold for lens opacities.
129	Phosphorus-32 (external)	2500-3000 rep	2 mo	Graying of fur.
130		5000 rep		Epilation, recovery by 10 wk.
131		7500 rep		Permanent epilation; ulcerations.
132		15000 rep		Emaciation.
133	Radium	100 μg in 90 da ($RaSO_4$ in glycerine, orally)	2 mo	Mottling and shortening of incisors.
134			5-18 mo	Pathological fractures; alopecia.
135			9 mo	Jaw abscesses, rarefaction of mandible and other bones (generalized osteoporosis and necrosis); weight loss; mild progressive regenerative anemia with hyperplasia and fibrosis of marrow, lymph nodes, and spleen.
136	Thorium dioxide ("thorotrast"), 20% colloidal suspension (α- and γ-rays)	i.v. injection		Osteosarcoma; hemopoietic depression and damage to liver and spleen. Deposited in reticulo-endothelial system.
137	X-ray	0.1-0.5 r/da	1 yr	No changes detected.
138		1.0 r/da	1 yr	Possible testicular injury.
139		10 r/da	8 wk	Lymphocytes significantly decreased.
140			3 mo	Platelets decreased.
141			1 yr	Erythrocytes decreased; testicular injury; ovarian follicles disappear.
142		250 r or leas (1, 2 Mev)	150 da	Threshold for production of lens opacities.
143		500 r	125 da	Cataracts, greatly affected by age, earlier in young rabbits.

[1] One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one r of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. [3] n/X-ray relative biological effectiveness (RBE) for production of opacities is 9 times the n/X-ray RBE for 30 da lethality.

413. IRRADIATIONS: LATE EFFECTS (Concluded)

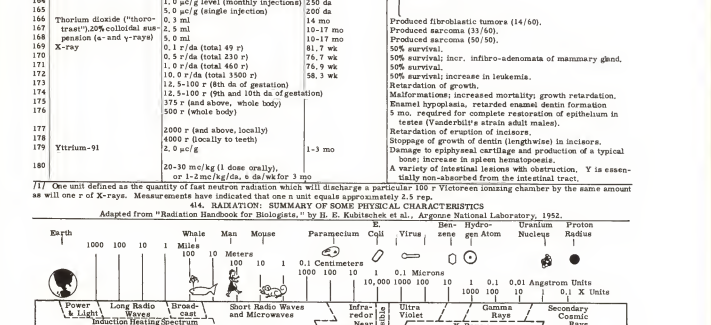
Ranges, when preceded by average values, are given in parentheses. c=curie; mc=millicurie; µc=microcurie; ev=electron volt; Mev=million electron volts; kv=1000 volts; n=n unit[1]; r=roentgen; rep=roentgen equivalent physical; rem=roentgen equivalent mammals; a=alpha rays; y=gamma rays.

	Radiation			
	Type	Amount	Latent Period	Late Effects
			kst (concluded)	
144	Cerium-144	1-3 mc/kg	200 da	Osteogenic sarcoma; liver atrophy with ascites and jaundice.
145	Cobalt-60 (y-rays),	20 r/da	332 da	50% survival; increased tumor frequency.
146	external	60 r/da	236 da	50% survival; increased tumor frequency.
147		70 r/da	72 da	50% survival; increased tumor frequency.
148		80 r/da	53 da	50% survival; increased tumor frequency.
149		90 r/da	48 da	50% survival; increased tumor frequency.
150		120 r/da	38 da	50% survival; increased tumor frequency.
151	Neutrons	0.012-0.06 n/da	1 yr	No effects observed.
152		0.11 n/da	1 yr	Number of neoplasms three times that of controls (including leukemias).
153		1.7 n/da	1 yr	Incr. infection and incidence of neoplasms (high leukemia incidence); bilateral cataracts; hypoplasia of spleen; atrophy of testes and ovarian follicles; early reduction of lymphocytes; reduction of erythrocytes.
154	Phosphorus-32	4000-5000 rep (external)	4-5 mo	Tumors; keratoses; lens opacities (low incidence); ulceration of scrotum and base of tail; alopecia.
155	Praseodymium-144	1-3 mc/kg	200 da	Osteogenic sarcoma; liver atrophy with ascites and jaundice.
156	Plutonium-239	0.02 µg/g (0.0031-0.0062 c/g)	300-400 da	Osteogenic sarcomas.
157		0.03 µc/g	3-7 mo	Areas of dead bone and calcified cartilage, resumption of normal bone growth at epiphysis; destruction of spermatogenic cells; atrophy of ovary.
158	Radium	0.125 µc/g	5 mo	Damage to epiphyseal cartilage, overgrowth with atypical bone, loss of normal bone cells; atrophy of ovary.
159		0.5 µc/g	3-6 mo	Degenerative changes in ovary; damage to blood vessels.
160		0.6 µc/g	5 mo	Damage to epiphyseal cartilage and marrow, production of abnormal bone.
161	Strontium-89	0.05 µc/g	500 da	Osteogenic sarcomas.
162		0.1 µc/g	400 da	
163		0.5 µc/g (single injection)	400 da	
164		1.0 µc/g level (monthly injections)	250 da	
165		5.0 µc/g (single injection)	200 da	
166	Thorium dioxide ("thoro-	0.3 ml	14 mo	Produced fibrohistic tumors (14/60).
167	trast"),20% colloidal sus-	2.5 ml	10-17 mo	Produced sarcoma (15/60).
168	pension (a- and y-rays)	5.0 ml	10-17 mo	Produced sarcoma (50/50).
169	X-ray	0.1 r/da (total 49 r)	81.7 wk	50% survival.
170		0.5 r/da (total 230 r)	76.7 wk	50% survival; incr. infibro-adenomata of mammary gland.
171		1.0 r/da (total 460 r)	76.9 wk	50% survival.
172		10.0 r/da (total 1500 r)	58.3 wk	50% survival; increase in leukemia.
173		12.5-100 r (8th da of gestation)		Retardation of growth.
174		12.5-100 r (9th and 10th da of gestation)		Malformations; increased mortality; growth retardation.
175		375 r (and above, whole body)		Enamel hypoplasia, retarded enamel dentin formation
176		500 r (whole body)		5 mo, required for complete restoration of epithelium in testes (Vanderbilt's strain adult males).
177		2000 r (and above, locally)		Retardation of eruption of incisors.
178		4000 r (locally to teeth)		Stoppage of growth of dentin (lengthwise) in incisors.
179	Yttrium-91	2.0 µc/g	1-3 mo	Damage to epiphyseal cartilage and production of a typical bone; increase in spleen hematopoesis.
180		20-30 mc/kg (1 dose orally), or 1-2 mc/kg/da, 6 da/wk for 3 mo		A variety of intestinal lesions with obstruction. Y is essentially non-absorbed from the intestinal tract.

[1] One unit defined as the quantity of fast neutron radiation which will discharge a particular 100 r Victoreen ionizing chamber by the same amount as will one r of X-rays. Measurements have indicated that one n unit equals approximately 2.5 rep.

414. RADIATION: SUMMARY OF SOME PHYSICAL CHARACTERISTICS

Adapted from "Radiation Handbook for Biologists," by H. E. Kubitschek et al., Argonne National Laboratory, 1952.



415. FACTORS AFFECTING RESPONSE TO X- AND GAMMA RADIATION

+ = increased; - = decreased; ± = no effect; i.p. = intraperitoneal; i.v. = intravenous.

Part I: PROPHYLACTIC FACTORS

Grouping of agents or measures is tentative and arbitrary as there is no general agreement concerning mechanism of action. Contradictory or conflicting results under similar conditions represent data reported by different investigators. Although there may be differences in the efficacy of the agents, it is not always possible to grade their effects on survival.

	Agent or Condition[1]	Animal	Time of Administration[2] (With Respect to Irradiation)	Survival	Other Effects
			Hypoxia (Physical)		
1	Anemia, bleeding-induced	Rat	Immediately before.		- sensitivity of skin and of Jensen rat sarcoma.
2	Anemia, bleeding-induced	Dog, rat	Immediately before or after.		Stimulation of erythropoiesis.
3	Carbon dioxide atmosphere	Mouse(newborn)	Immediately before and during.	+	
4	Hypothermia	Mouse(newborn)	Immediately before and during.	+	
5	Hypothermia	Rat (newborn)	Immediately before and during.		- skin sensitivity.
6	Interference with respiration[3]	Rat (newborn)	Immediately before and during.		
7	Lowered ambient oxygen tension	Mouse	Immediately before and during.	+	- incidence of abnormal mitoses in bone marrow.
8	Lowered ambient oxygen tension	Mouse	Immediately before and during.		No protection vs induction of dominant lethal mutations.
9	Lowered ambient oxygen tension	Rat	Immediately before and during.	+	
10	Lowered ambient oxygen tension	Mouse(in utero)	Immediately before and during.		- developmental abnormalities.
11	Nitrogen atmosphere	Mouse(newborn)	Immediately before and during.	+	
			Hypoxia (Chemical)		
12	p-Aminopropiophenone	Rat, mouse	Immediately before.	+	
13	p-Aminopropiophenone	Rat	Immediately before or after.		Stimulation of erythropoiesis.
14	Carbon monoxide (inhalation)	Mouse	Immediately before and during.	+	
15	Epinephrine	Rat	Immediately before.	+	
16	Hydrogen sulfide (inhalation)	Mouse	Immediately before and during.	+	
17	Methylene blue	Mouse	Immediately before.	+	
18	Morphine	Mouse	Immediately before.	+	
19	Piperesin	Rat	Immediately before.	+	
20	Sodium nitrite	Mouse	Immediately before.	+	
			Bone Marrow Hyperplasia		
21	Bleeding	Rabbit	Several da before.		+ resistance of erythropoietic tissue.
22	Cobalt	Mouse	Fed in diet several da before.	+	
23	Estrogens	Mouse	5 to 15 da before.	+	
24	High altitude (simulated)	Mouse	Repeatedly several da before.		+ resistance of erythropoietic tissue.
25	High altitude (simulated)	Rat	Repeatedly several da before.	-	- protection of DNA synthesis in bone marrow and spleen.
26	Phenylhydrazine	Rabbit	Repeatedly several da before.		+ resistance of erythropoietic tissue.
			Amines[4]		
27	Glucosamine	Mouse	Immediately before.	+	
28	Hydroxylamine	Mouse	Immediately before.	+	
29	5-Hydroxytryptamine	Rat	Immediately before.	+	
30	Isopropylamine	Mouse	Immediately before.	+	
31	Methylamine	Mouse	Immediately before.	+	
			Sulfhydryl Compounds[5]		
32	2-Aminoethyl disulfide	Mouse	Immediately before.	±	
33	Cysteine	Mouse	Immediately before.	-	- leukopenia, - splenic atrophy.
34	Cysteine	Mouse	Immediately before.		Additive with hypoxia in reducing incidence of abnormal mitoses in marrow.
35	Cysteine	Rat	Immediately before.	+	- depression and more rapid recovery of WBC and RBC.
36	Cysteine	Rabbit	Immediately before.		- incidence of nuclear fragmentation in ocular lens epithelium.
37	Cysteine	Rabbit	Immediately before[6]		- histological damage to cornea following beta radiation.
38	2,3-Dimercapto-1-propanol(BAL)	Rat, mouse	Immediately before.	+	
39	Glutathione	Mouse, rat	Immediately before.	+	No difference in initial destructive effects of radiation but more rapid recovery of hematopoietic and lymphopoietic tissues.
40	β-Mercaptoethylamine[7]	Mouse	Immediately before.	+	More rapid recovery of white blood cell count; no protection against mutagenic effects.
41	β-Mercaptoethylamine	Rat	Immediately before.	+	Prevented radiation-induced increase in adrenal weight and late fall in adrenal cholesterol.
42	Monothiol glycerol	Mouse	Immediately before.	+	
43	Sodium ethanedithiophosphonate	Mouse	Immediately before.	+	
44	Thiosorbitol	Mouse	Immediately before.	+	
45	Thiourea	Mouse	Immediately before.	+	
			Miscellaneous		
46	Atropine	Mouse	Daily before and after.	+	
47	Carbamoylcholine chloride	Mouse	Immediately before.	+	
48	Ethanol	Mouse	Immediately before.	+	
49	Glycerol	Mouse	Immediately before.	+	
50	Malononitrile	Mouse	Immediately before.	+	
51	Mecbolyl bromide or chloride	Mouse	Immediately before.	+	
52	Propylene glycol	Mouse	Immediately before.	+	
53	Serum, foreign	Mouse	10 days before.	±	
54	Serum, foreign	Rabbit	10 days before.		- severity of skin reaction.
55	Serum, foreign	Dog	7 days before.		- leukopenia, + general health.
56	Serum or plasma[8]	Mouse	Immediately before.	±	
57	Sodium azide	Mouse	Immediately before.	+	
58	Sodium or potassium cyanide	Mouse	Immediately before.	+	
59	Sodium or potassium cyanide	Rat	Immediately before.	±	
60	Terramycin	Rat	Repeatedly for 48-72 hr before.	+	

/1/ Unless otherwise indicated, chemical agents given by parenteral injection. /2/ "Immediately before" indicates a few minutes to 1 hour previous to radiation exposure. /3/ Taping of chest. /4/ Do not contain sulfhydryl groups. /5/ Some of these agents do not contain the sulfhydryl group, but it is believed that in vivo a sulfhydryl linkage is encountered; for instance, 2-aminoethyl disulfide (cystinamine) is converted in vivo to β-mercaptoethylamine (cysteamine). /6/ Local administration. /7/ The mercaptoethylamine derivative β-aminoethylisothiouranium is somewhat less toxic to mice, and more stable than its parent compound. /8/ Homologous or heterologous.

415. SOME FACTORS AFFECTING RESPONSE TO X- AND GAMMA RADIATION (Concluded)

+ = increased; - = decreased; ± = no effect; i.p. = intraperitoneal; i.v. = intravenous.

Part II: THERAPEUTIC FACTORS

	Agent	Animal[1]	Method of Administration	Effect on Survival
			Antibiotics	
1	Aureomycin	Mouse, rat, guinea pig, dog	Daily by various routes and dosage schedules.	± to slight +.
2	Streptomycin	Mouse	Daily injections, various dosages.	Significant +.
3	Streptomycin	Swine	Daily injections after combined X-ray exposure and thermal burns.	+.
4	Terramycin	Mouse, rat	Various dosages, dosage schedules, methods of administration.	± to slight +.
5	Terramycin	Dog	Orally, 100 mg/kg/da for 28 da.	+.
6	Antibiotics, wide variety, various combinations	Mouse, rat, guinea pig	Various routes, dosages, dosage schedules.	± to slight +.
			Transfusion of Blood and Various Blood Components	
7	Blood, whole	Dog	Exchange transfusion[2] within a few hr.	± to slight +.
8	Blood, whole	Dog	Repeated transfusions.	±.
9	Blood, whole, plus aureomycin	Dog	Repeated transfusions plus aureomycin in various dosage schedules.	±.
10	Leukocytes	Dog	Daily transfusion of leukocyte suspensions.	Survival data inadequate; leukocytes migrate to foci of infections.
11	Platelets	Dog	Repeated transfusions of platelet suspensions	Survival data inadequate; control of hemorrhages.
			Spleen and Bone Marrow Inoculations	
12	Spleen	Mouse, rat	Implant, or i. p. injection of homologous homogenate within a few min to 2 da.[4]	Marked + (mouse spleen); ± (rat spleen).
13	Spleen	Mouse	Implants to anterior chamber of eye.	+.
14	Marrow, bone	Mouse, rat	i.p. inoculation of homologous marrow within a few min to 2 da.	Marked +.
			Miscellaneous	
15	Bone	Mouse	i.p. inoculation of ground bone 1-2 hr.	+.
16	Parabiosis	Rat	Para-biotic union of normal and irradiated rats within a few hr to several da.	+.
17	Properdin	Mouse, rat	I. v. injection.	+, if any.

/1/ Animals exposed to total-body radiation. /2/ Combined penicillin and streptomycin increased survival in dog. /3/ Cross circulation. /4/ Homologous rat spleen implants or intraperitoneal injections into X-irradiated rats is far less effective than similar mouse spleen therapy in irradiated mice.

416. RADIATION BIOLOGY: GLOSSARY

ALPHA PARTICLE (a): Positively charged particle emitted by radioactive atomic nuclei; usually travelling at high speed, and having a mass number 4 and atomic number 2. ALPHA RAY (a): Stream of alpha particles. ANGSTROM (Å): A unit of length, used chiefly in expressing short wave lengths; it equals 10^{-8} cm. ATOM: Smallest particle of an element which is capable of entering into a chemical reaction. ATOMIC MASS UNIT (amu): Exactly 1/16 of the mass of a neutral atom of the most abundant isotope of oxygen, O^{16}. One amu = 1.660×10^{-24} g = 931 mev = 0.999728 awu: ATOMIC NUMBER (Z): Number of orbital electrons in a neutral atom, or the electric charge on the nucleus of an atom, or the number of protons in the nucleus of an atom. ATOMIC WEIGHT: Relative weight of an atom compared with the weight of 1 atom of oxygen taken at 16. ATOMIC WEIGHT (chemical scale): Average weight of the atoms of an element (of isotope distribution found in nature) referred to the weight of exactly 16 for the average weight of the atoms of oxygen of isotope distribution found in fresh lake or rain water. Atomic weights on the chemical scale are expressed as atomic weight units (awu). The value may be computed from atomic weights on the physical scale by: atomic weight ÷ 1.000272. ATOMIC WEIGHT (physical scale): Weight of an atom or the average weight of a mixture of atoms of an element referred to the exact value 16 for the principal isotope of oxygen, O^{16}. Atomic weights on the physical scale are expressed in atomic mass units (amu). They may be computed from atomic weights on the chemical scale by atomic weight x 1.000272. ATOMIC WEIGHT UNIT (awu): Exactly 1/16 of the weighted mean of the masses of the neutral atoms of oxygen of isotopic composition found in fresh lake or rain water. 1 awu = 1.660×10^{-24} g = 1.000272 amu. ATTENUATION: Term often used to indicate the decrease in number of particles as a function of thickness of the absorbing medium, and this number of particles may or may not be proportional to the dose because specific ionization changes with the velocity of the particles. BETA PARTICLE (β): Electron, negative or positive (positron), emitted from the nucleus during radioactive disintegration. (Symbols β_0, β^-, β^+ are reserved for electrons of nuclear origin.) BETA RAY (β): Stream of beta particles. COLLIMATED: Beam of radiation limited to the required dimensions. COSMIC RAYS: Ionizing rays entering the earth's atmosphere from unidentified extra-terrestrial space and resulting in the presence of photons, electrons, neutrons, protons, mesons, etc., by collisions with atoms in the atmosphere and by radioactive decay. Most penetrating of all radiations. COULOMB: Practical unit of electrical charge. CURIE (c): A unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.7×10^{10}. DECAY, RADIOACTIVE: The spontaneous transformation with a measurable life-time of a nuclide into one or more different nuclides. The process involves the emission from the nucleus of alpha particles, electrons, positrons, gamma rays, neutrons or the nuclear capture or ejection of orbital electrons. Rate of decay is usually expressed in terms of half-life. DEUTERIUM (H^2): The hydrogen isotope of mass number 2 (1 proton, 1 neutron, 1 electron). It has an amu of 2.01474 ± 0.00002. DEUTERON: The nucleus of deuterium (1 proton, 1 neutron). It has an amu of 2.01419 ± 0.00002. DISINTEGRATION: Process of spontaneous breakdown of a nucleus of an atom resulting in the emission of a particle and/or a photon. DOSE: A quantity of radiation as defined in the definition of the unit "roentgen." DOSE ABSORBED (any ionizing radiation): Amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It shall be expressed in rads (I.C.R.U., 1953). Absorbed dose rate is the absorbed dose per unit of time. DOSE, AIR (free air dose): A dose of radiation measured in air at the point of interest, or in the absence of patient (or phantom) or other object, thus excluding secondary radiation, apart from that arising from the air or associated with the source. DOSE, PERMISSIBLE: Dose of ionizing radiation (within a specified period) that, in the light of present knowledge, is not expected to cause appreciable bodily injury to a person at any time during his lifetime. DOSE, PERMISSIBLE WEEKLY: Dose of ionizing radiation accumulated in one week of such magnitude that, in the light of present knowledge, exposure at this weekly rate for an indefinite period of time is not expected to cause appreciable bodily injury to a person at any time during his lifetime. (For long-continued X- or gamma ray exposure of the whole body it is 0.3 r/wk measured in air.) DOSE RATE: Radiation dose received per unit of time.

DYNE: Unit of force capable of producing an acceleration of 1 cm/sec/sec to 1 g. ELECTROMAGNETIC UNIT (emu): Relates magnetic field to electric current, 3×10^{10} esu of charge = 10 coulombs (the practical unit of charge) = 1 emu. ELECTRON (e^- or β^-): Subatomic particle having a rest mass of (9.1086 ± 0.0003) x 10^{-28} g, or 1/1836 x mass of a proton, and a charge of negative electricity of (4.80294 ± 0.00008) x 10^{-10} esu. (Synonym is "negatron.") ELECTRON CAPTURE (EC): Radioactive transformation occurring when a bound electron merges with the nucleus, converting a proton to a neutron, with liberation of energy in the form of a monoenergetic neutrino plus a photon of X-ray characteristic of the new substance. It is a type of beta decay. Electron capture, identified with a literal prefix (e.g., K-electron capture), refers to capture of electrons initially in the designated atomic shell. ELECTRON VOLT (ev): Unit of energy. The change in kinetic energy of an electron when it is accelerated through a potential difference of 1 volt. One ev is equivalent to 1.602×10^{-12} erg. 100 ELECTRON VOLT YIELD (100 ev yield): Yield of molecules converted or produced per 100 ev of radiant energy input. ELECTROSTATIC UNIT OF CHARGE (esu): The amount of electrical charge which, in a vacuum, will repel a like charge with a force of 1 dyne at a distance of 1 cm. FISSION, NUCLEAR: The splitting of a nucleus into more-or-less equal fragments. Fission may occur spontaneously or may be induced by capture of bombarding particles. In addition to the fission fragments, neutrons and gamma rays are usually produced during fission. GAMMA RAY (γ): Electromagnetic radiation of short wave length and correspondingly high frequency, emitted by the nucleus of an atom in the course of radioactive decay. (There is no distinction between X-ray photons and gamma ray photons of the same energy.) HALF-LIFE, RADIOACTIVE: Time taken for the amount of a radioactive nuclide to decay to half its initial value. HALF-VALUE LAYER (HVL): The thickness of a specified absorbing material which, when introduced into the path of an X-ray beam, reduces the dose rate to 1/2 its original value. Also, half-value layer is applied to that layer which reduces the number of radioactive particles, and in many cases the absorbed dose rate, to the half-value. ISOTOPE: One of several nuclides having the same number of protons in their nuclei, hence belonging to the same element and having the same atomic number Z, but differing in the number of neutrons and therefore in mass number A. KILO-ELECTRON-VOLT (kev): 1000 electron volts. KILO-ROENTGEN (kr): 1000 roentgens. KILOVOLT (kv): A unit of electrical potential equal to 1000 volts. KILOVOLT PEAK (kvp): The crest value of the potential wave in kilovolts. MASS: Quantity of matter. MASS or NUCLEON NUMBER (A): Total number of nucleons (protons and neutrons) in the nucleus of an atom or nuclide. MEGA- or MILLION ELECTRON VOLT (Mev): 1,000,000 electron volts (unit of energy equal to 1.6×10^{-6} ergs). MESON: An elementary particle having a rest mass intermediate between the mass of an electron and that of a proton. All of the known mesons are unstable and short-lived. The meson is a quantum of the nuclear field. MICROCURIE (μci): 1/1,000,000 of a curie (3.7 x 10^4 disintegrations per second). MICROROENTGEN (μr): 1/1,000,000 of a roentgen. MILLIAMPERE (ma): 1/1000 of an ampere. MILLICURIE (mc): 1/1000 of a curie (3.7 x 10^7 disintegrations per second). MILLIRAD (mrad): 1/1000 of a rad. MILLIROENTGEN (mr): 1/1000 of a roentgen. MILLIROENTGEN EQUIVALENT PHYSICAL (mrep): Amount of energy absorption in soft tissue corresponding to 0.093 ergs per gram. MOLECULE: Ultimate unit quantity of a compound which can exist by itself and retain all the properties of the original substance. NEGATRON (β^-, or e^-): A negative electron (a term sometimes used when necessary to distinguish between positive and negative electrons). NEUTRINO: A theoretical particle of very small rest mass very nearly equal to zero, emitted in beta decay and other nuclear reactions. NEUTRON (n): A nuclear particle of zero charge and mass number 1; the mass is 1.00898 ± 0.00002 amu. (Neutrons are a constituent of all nuclei except H^1.) The neutron has a mass slightly greater than that of the proton. NEUTRON, FAST: A neutron possessing high kinetic energy. NEUTRON, SLOW: A neutron slowed in passage through a scattering material. NEUTRON, THERMAL: Neutron with kinetic energy distribution comparable with the kinetic energy distribution caused by thermal agitation of the nuclei composing the medium. NUCLEON: A constituent particle of the atomic nucleus (proton, neutron), NUCLIDE: A species of atom having a specific mass number (A), atomic number (Z), and atomic mass. PHOTON: Quantum (quantum) manifestation of electromagnetic radiation. POSITON (β^+, or e^+): A subatomic particle having a rest mass of (9.1086 ± 0.003) x 10^{-28} g, and a charge of positive electricity of (4.80294 ± 0.00008) x 10^{-10} esu. a positive electron. PROTECTIVE BARRIER: Barrier of radiation-absorbing material, such as lead, concrete, etc., used to reduce radiation hazards. PROTECTIVE HARRIER, PRIMARY: Barrier sufficient to reduce the useful beam to the maximum permissible weekly dose. PROTIUM (H^1): Hydrogen isotope of mass 1. PROTON: An elementary nuclear particle of mass 1 having a charge equal and opposite to that of an electron. The rest mass is (1.6724 5 ± 0.00005) x 10^{-24} g, or 1.0076 amu. (The nucleus of H^1 is a proton; the proton is one of the constituents of every nucleus.) PULSATING POTENTIAL (or VOLTAGE): A potential (or voltage) which undergoes large periodic variations in magnitude at a frequency related to that of the main supply. QUANTUM: The smallest quantity of energy constituting a photon of electromagnetic radiation which can be associated with a given phenomenon. (Electromagnetic radiation sometimes appears to consist of waves and at other times of particles.) QUANTUM ENERGY: Energy contained in a quantum of radiation and proportional to the frequency of the radiation waves. RAD (rad): Unit of absorbed dose: it is the energy absorption of 100 ergs/g of any medium. RADIATION: Emission and propagation of energy through space or through a material medium as (a) electromagnetic or elastic waves (X-, gamma, infrared, visible, and ultraviolet rays), and (b) by extension, corpuscular emissions such as alpha, beta, neutron and proton radiation, and mixed or unknown rays such as cosmic rays. RADIATION, BACKGROUND: Undesired radiation arising from radioactive material other than that directly under consideration, i.e., cosmic rays, natural radioactivity, insulator leakage, power-line fluctuations, etc. RADIATION HEAVY PARTICLE: Particulate ionizing radiation consisting of atomic nuclei of any mass travelling at high speed. Alpha particles or rays constitute a special kind of heavy particle radiation. RADIATION, IONIZING: Electromagnetic ionizing radiation (X- or gamma ray photons or quanta), or corpuscular radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons and heavy particles) capable of producing ions directly or by secondary processes. RADIATION, LEAKAGE: In the case of X-rays all radiation, except the useful beam, coming from within the X-ray tube and tube housing. RADIATION, PRIMARY: Radiation coming directly from the source, i.e., target of the X-ray tube ("useful beam" and leakage radiation), or radioactive material (beta and gamma rays). RADIATION, SCATTERED: Radiation which, during passage through a substance, has been deviated in direction, and may also have been modified by increase in wave length (Compton effect) and have had its energy diminished. It is one form of secondary radiation. RADIATION, SECONDARY: Radiation, other than primary radiation, emitted by any matter irradiated with X-rays, gamma rays, electrons, neutrons, etc.; it may consist of X-rays, gamma rays, electrons, protons, neutrons, etc., or ultraviolet or visible radiation. RADIATION, STRAY: Radiation not serving any useful purpose. It includes leakage radiation, and secondary radiation from irradiated objects, and represents the portion of the radiation against which special protective measures have to be taken. RADIATION, USEFUL BEAM: That part of the primary and secondary radiation which passes through the aperture, cone, or other device for collimating the X-ray beam. RADIATION HAZARD: Danger to health arising from exposure to ionizing radiation. X-ray beam, produces the dose rate to 1/2 its original value. Also, half-value layer is applied to that layer which reduces the number of radioactive particles, and in many cases the absorbed dose rate, to the half-value. ISOTOPE: One of several nuclides having the same number of protons in their nuclei, hence belonging to the same element and having the same atomic number Z, but differing in the number of neutrons and therefore in mass number A. KILO-ELECTRON-VOLT (kev): 1000 electron volts. KILO-ROENTGEN (kr): 1000 roentgens. KILOVOLT (kv): A unit of electrical potential equal to 1000 volts. KILOVOLT PEAK (kvp): The crest value of the potential wave in kilovolts. MASS: Quantity of matter. 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RADIATION, USEFUL BEAM: That part of the primary and secondary radiation which passes through the aperture, cone, or other device for collimating the X-ray beam. RADIATION HAZARD: Danger to health arising from exposure to ionizing radiation. It may be caused by external radiation or by radiation from radioactive materials within the body. RADIOACTIVITY: Spontaneous disintegration of an unstable nuclide with the emission of a particle or a photon to form a different nuclide. RADIOISOTOPE: Any radioactive isotope of an element. (Also loosely used as a synonym for nuclide.) RELATIVE BIOLOGICAL EFFECTIVENESS (RBE): The appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received. The RBE is expressed in terms of the permissible weekly dose in terms taken as 1. ROENTGEN (r): The quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electricity of either sign. ROENTGEN EQUIVALENT MAN (OR MAMMAL) (rem): The absorbed dose of any ionizing radiation which has the same biological effectiveness as one rad of X-radiation with average specific ionization of 100 ion pairs per micron of water, in terms of its air equivalent, in the same region. A dose in rem is equal to the dose in rads multiplied by the RBE. ROENTGEN EQUIVALENT PHYSICAL (rep): The dose of ionizing radiation which produces energy absorption of 93 ergs per gram of soft tissue (rep is being superseded by rad). ROENTGEN RAYS: X-rays, usually produced by bombarding a metallic target with high-speed electrons in a suitable device. TELETHERAPY: Therapeutic irradiation with collimated gamma rays. TRITIUM (H^3, or T): The hydrogen isotope of mass number 3 (1 proton, 2 neutrons, 1 electron). It has an amu of 3.01695, and half-life of 12.5 yr. VOLT (v): Practical unit of electric potential, i.e., that potential difference against which 1 joule of work is done in the transfer of 1 coulomb. One volt is equivalent to 10^8 electromagnetic units of potential. X-RAY: Electromagnetic ionizing radiation which originates outside the nucleus of the atom, and results from loss of energy of charged particles, e.g., electrons. It is of shorter wave length (less than about 100 Å) than ultraviolet radiation.

417. ALIMENTARY TRACT MICROORGANISMS

Part I: NORMALLY OCCURRING: MAN

	Organism	Habitat[1] Mouth	Ileum	Cecum	Appendix	Colon
	Bacteria					
1	Aerobacter aerogenes		+	+	+	+
2	A. cloacae		+	+	+	+
3	Alcaligenes faecalis		+	+	+	+
4	Bacteroides spp		+	+	+	+
5	Clostridium alcaligenes		+	+	+	+
6	C. angulosum		+	+	+	+
7	C. bifermentans		+	+	+	+
8	C. filamentosum		+	+	+	+
9	C. perfringens		+	+	+	+
10	C. tertium		+	+	+	+
11	C. tetani		+	+	+	+
12	Dialister granuliformans	+				
13	D. pneumosintes	+				
14	Diplococcus pneumoniae	+				
15	Escherichia coli		+	+	+	+
16	E. freundii		+	+	+	+
17	Fusobacterium plautivincenti	+				
18	Gaffkya anaerobia		+	+	+	+
19	G. tetragena	+	+	+	+	+
20	Klebsiella pneumoniae	+	+	+	+	+
21	Lactobacillus spp	+	+	+	+	+
22	Micrococcus pyogenes var. albus	+	+	+	+	+
23	M. pyogenes var. aureus	+	+	+	+	+
24	Neisseria catarrhalis	+				
25	N. sicca	+				
26	Proteus mirabilis		+	+	+	+
27	P. morganii		+	+	+	+
28	P. rettgeri		+	+	+	+
29	P. vulgaris		+	+	+	+
30	Streptococcus anaerobius	+	+	+	+	+
31	S. durans		+	+	+	+
32	S. faecalis		+	+	+	+
33	S. foetidus	+	+	+	+	+
34	S. liquefaciens		+	+	+	+
35	S. mitis	+				
36	S. pyogenes	+				
37	S. salivarius	+				
38	S. symogenes		+	+	+	+
39	Veillonella gazogenes	+				
40	V. parvula	+				
	Fungi					
41	Candida albicans	+	+	+	+	+
42	C. krusei		+	+	+	+
43	C. tropicalis		+	+	+	+
44	Cryptococcus spp		+	+	+	+
45	Debaryomyces klocheri	+				
46	Geotrichum brasiliensis		+	+	+	+
47	Mycoderma pulmonsum		+	+	+	+
48	Saccharomyces spp		+	+	+	+
49	S. tumefaciens albus	+				

/1/ Bacteria and fungi are not normally present in the stomach, duodenum and jejunum.

Part II: FECAL CONTENT: MAN

Values are on a dry weight of feces basis, unless otherwise indicated; those in parentheses are ranges. Superscripts after numerical values are exponents, not footnotes.

	Species or Group of Orgaoisms	Organisms Units	Value
1	Bacterial content, total	grams per day	8.3
2	(living and dead)	% of feces	28(20–35)
3		No./g feces[1]	$(10–80x10^{10})$
4		Total no.	$30x10^{12}$
5	Living bacteria: aerobic agar	No./g feces	$(14x10^{8}–15x10^{8})$
6	Living bacteria: anaerobic agar	No./g feces	$(30x10^{8}–12x10^{9})$
7	Gram-neg. bacteria, total	% of all bact.	81(63–97)
8	Gram-neg. rods		71(55–91)
9	Gram-neg. cocci	% of all	8(1–37)
10	Gram-neg. spirilla	bacteria	0.1(0–0.2)
11	Gram-neg. spirochetes		1.1(0–11)
12	Gram-pos. bacteria, total	% of all bact.	17(1–34)
13	Gram-pos. cocci	% of all	11(0.4–32)
14	Gram-pos. rods	bacteria	6(1–13)
15	Gram-pos. rods with spores	% of all	0.4(0–0.8)
16	Free spores	bacteria	2(0–14)
17	Microbial flora, living[2] Escherichia coli[3]	No./g feces	$(10^{8}–10^{9})$
18		% of gram-neg.	65
19		% of subjects[4]	93
20	Aerobacter aerogenes	% of gram-neg.	0.2
21		% of subjects[4]	47
22	Intermediates (gram-neg.)	% of gram-neg.	34.8
23	Bacilli, anaerobic[5]	No./g feces[1]	$(10^{6}–10^{12})$
24	Lactobacilli[6]	No./g feces	$(10^{6}–10^{10})$
25	Monilia	% of subjects[4]	Few in 33%
26	Other fungi	% of subjects[4]	Few in 3-29%
27	Streptococci (S. faecalis)	No./g feces	$(10^{2}–10^{7})$

/1/ Wet. /2/ In addition to organisms listed, Clostridia (mainly C. perfringens and C. tetani), Micrococci, Proteus and Pseudomonas spp. and various Bacteriodes are frequently found in feces. /3/ Various sero- and bio-types, transient and resident. /4/ Present in feces in this percentage of adults. /5/ Non-sporulating. /6/ Non-sporulating, including Lactobacilli and Bacteroides.

Part III: ALIMENTARY TRACT: MAMMALS AND BIRDS

Values in parentheses are ranges. Superscripts after numerical values are exponents, not footnotes. Values are on wet weight basis.

	Animal	Source of Organisms	Species or Group of Organisms	Organisms per g wet wt
1	Calf[1]	Feces	Aerobes	$(2–940x10^{7})$
2			Anaerobes	$(150–950x10^{7})$
3			Coliforms	$(2–280x10^{7})$
4			Enterococci	$(10–700x10^{3})$
5		Stomach	Anaerobic sporing rods	10^{3}
6			L. acidophilus var. caviae	$(10^{5}–10^{6})$
7			Yeast-like organisms	$(10^{3}–10^{4})$
8		Duodenum-jejunum	Anaerobic sporing rods	10^{3}
9			Enterococci	10^{3}
10			L. acidophilus var. caviae	$(10^{5}–10^{6})$
11			Yeast-like organisms	$(10^{4}–10^{5})$
12		Ileum	Anaerobic sporing rods	10^{3}
13			Enterococci	10^{3}
14			L. acidophilus var. caviae	$(10^{6}–10^{7})$
15			Yeast-like organisms	$(10^{4}–10^{5})$
16	Guinea pig[2]	Cecum	Anaerobic sporing rods	10^{3}
17			Enterococci	$(10^{3}–10^{7})$
18			L. acidophilus var. caviae	$(10^{5}–10^{8})$
19			Yeast-like organisms	$(10^{3}–10^{5})$
20		Colon	Anaerobic sporing rods	10^{3}
21			Enterococci	$(10^{3}–10^{8})$
22			L. acidophilus var. caviae	$(10^{5}–10^{7})$
23			Yeast-like organisms	$(10^{3}–10^{5})$
24		Rectum	Anaerobic sporing rods	10^{3}
25			Enterococci	$(10^{3}–10^{5})$
26			L. acidophilus var. caviae	$(10^{5}–10^{7})$
27			Yeast-like organisms	$(10^{4}–10^{5})$
28	White rat	Pooled feces	Aerobic flora, total	$(20–95x10^{8})$
29			Anaerobic flora, total	$(45–200x10^{8})$
30			Coliform bacteria	$(25x10^{3}–95x10^{6})$
31			Lactobacilli	$(6–36x10^{8})$
32			Spore-formers, anaerobic	$(2–85x10^{8})$
33		Duodenum	Coliform bacteria	$(10^{3}–10^{7})$
34			Enterococci	$(10^{3}–10^{8})$
35			Lactic acid bacteria	$(10^{3}–10^{8})$
36		Ileum	Coliform bacteria	$(10^{4}–10^{7})$
37			Enterococci	$(10^{5}–10^{8})$
38	Chicken		Lactic acid bacteria	$(10^{5}–10^{10})$
39		Cecal pouch	Coliform bacteria	$(10^{6}–10^{11})$
40			Enterococci	$(10^{6}–10^{8})$
41			Lactic acid bacteria	$(10^{9}–10^{11})$
42		Colon	Coliform bacteria	$(10^{6}–10^{9})$
43			Enterococci	$(10^{6}–10^{8})$
44			Lactic acid bacteria	$(10^{8}–10^{11})$
45	Turkey	Cecal feces	Bacterium spp, other misc. Gram-pos. rods (L. bifidus types)	$(0.7–10x10^{9})$
46			Coliform types	$(10^{8}–10^{8})$
47			Corynebacterium spp	$(0.2–10x10^{9})$
48			Enterococci	$(10^{4}–30x10^{9})$
49			Lactobacilli, facultative anaerobic (L. acidophilus types)	$(2x10^{5}–10^{8})$
50			Micrococci (Pediococcus types)[3]	$(10^{8}–30x10^{9})$
51			Streptococci, anaerobic	$(10^{8}–10^{8})$

/1/ Values are per gram dry weight of samples from calves 1-12 weeks old. /2/ Results with 4 different diets or under starvation conditions.
/3/ Aerobic and faculative anaerobic.

Organisms listed are only those which have been given scientific names, plus unnamed organisms appearing frequently in current literature. They account for only a few of the numerous bacteria that can be isolated from rumen fluid, and do not include many of the important fiber digesters.

	Organism	No. per ml of Rumen Contents	Morphology	Oxygen Relations	Principal End Products of Fermentation	Possible Role in the Rumen
1	Bacteroides succinogenes	$4x10^7$-$4x10^8$	Gram-neg., non-motile, slightly curved, small rods with pointed ends on cellulose agar.[1]	Anaerobic.	Acetic and succinic acids, and uptake of CO_2 from cellulose.	Vigorous cellulose digesters.
2	Borrelia sp	to 10^8	Gram-neg., small, slender, irregulary coiled spirochete with pointed end. Not double contoured.	Anaerobic.	Acetic and succinic acids, with smaller amounts of CO_2, ethanol, formic and lactic acids from glucose.	Fermenter of readily available carbohydrates such as hydrolytic products of starch and cellulose.
3	Butyrivibrio fibrisolvens[2]	to $5x10^8$	Gram-neg., curved, anaerobic rods with monotrichous flagella.	Anaerobic.	CO_2, H_2, and butyric, lactic and formic acids from glucose. Acetic acid produced or used.	Fermenter of fiber and readily available carbohydrates.
4	"Cellulolytic cocci"[3]	10^8-$4x10^8$	Gram-pos. to gram-neg., iodophilic cocci; diplococci to long chains.	Anaerobic.	CO_2, H_2, ethanol, lactic, acetic, formic, succinic acids from cellulose (Hungate). Acetic, formic and succinic acids (Slipestejh).	Vigorous digesters of cellulose and xylan.
5	Escherichia coli[4]	to 10^6	Small, gram-neg. rods.	Facultative anaerobe.	Lactic, acetic, formic, succinic acids, ethanol, CO_2 and H_2 from glucose.	Possibly none.
6	Lachnospira multiparus	to 10^8	Weakly gram-pos., curved rods with monotrichous flagella.	Anaerobic.	CO_2, H_2, ethanol and acetic, formic and lactic acids.	Fermenter of readily available carbohydrates.
7	Anaerobic lactobacilli[5]	to 10^9	Gram-pos. rods of various sizes and shapes, including branched rods.	Anaerobic; some revert to facultative anaerobes.	Lactic acid from glucose.	Fermenters of readily available carbohydrates.
8	Lactobacillus brevis[6]	to $3x10^6$	Gram-pos. rods with rounded ends; short in length to long filaments.	Facultative anaerobe.	Lactic acid from glucose.	Fermenter of readily available carbohydrates.
9	LC[7]	to 10^9	Gram-variable large diplococci.	Anaerobic.	CO_2, H_2, acetic, butyric, caproic, and small amount of propionic and valeric acids from glucose.	Fermenter of lactate, readily available carbohydrates and amino acids.
10	Propionibacterium acnes[8]	$2x10^5$-$7x10^9$	Gram-pos., short rods, metachromatic granules, some branching and longer under acid conditions.	Prefer anaerobic conditions.	Acetic and propionic acids and CO_2 from glucose or lactate.	Fermenter of lactate and readily available carbohydrates; also proteolysis.
11	Sarcina bakeri	to $1.4x10^5$	Large, gram-neg. cocci in pairs, tetrods and larger groups.	Facultative anaerobe.		
12	Selenomonas ruminantum[9]	to 10^8	Gram-neg., large, crescentic rods; tuft of flagella usually attached to concave side of cell.	Anaerobic.	Propionic, acetic and lactic acids from glucose. Propionic and acetic acids from lactate.	Fermenter of readily available carbohydrates. Some strains ferment lactate.
13	Streptococcus bovis[10]	10^5-$6x10^9$	Gram-pos. cocci in pairs; occasionally short chains.	Facultative anaerobe.	Lactic acid from glucose.	Active starch hydrolyzer; fermenter of readily available carbohydrates.
14	Succinivibrio dextrinosolvens[11]	to 10^7	Gram-neg., curved rods with monotrichous flagella.	Anaerobic.	Succinic and acetic acids from glucose.	Fermenter of the hydrolytic products of starch and other readily available carbohydrates.
15	Veillonella gasogenes	to 10^5	Gram-neg. to gram-variable masses of cocci.	Anaerobic.	Acetic and propionic acids, CO_2 and H_2 from lactate.	Fermenter of lactate and other organic acids and purines.

/1/ In sugar media, organisms may be larger, swollen, and exhibit bipolar staining. /2/ Similar to RO-H types of Huhtanen and Gall. /3/ A heterogeneous group requiring more study before species are designated. /4/ In large numbers only in sheep and very young calves. /5/ Predominantly in young calves and mature ruminants on rations with large amounts of readily available carbohydrates. /6/ These organisms have been isolated only from calves. /7/ Similar to RO-C8 of Huhtanen and Gall. /8/ Similar to RO-C1 of Huhtanen and Gall. /9/ Includes RO-HD types of Huhtanen and Gall. /10/ In large numbers only in animals receiving large amounts of readily available carbohydrates. /11/ Present in large numbers only in animals fed high grain ration.

Part I: DISEASE VECTORS

Unless otherwise indicated in the right-hand column ("Relationship"), infection or infestation is transmitted to man when bitten by the arthropod vector or host.

	Vector	Etiologic Agent	Disease or Infestation	Arthropod-Pathogen-Infection Relationship
			Crustacea (Crabs, Lobsters)	
1	Crabs and crayfish, fresh-water	Paragonimus westermani.	Paragonimiasis (pulmonary distomiasis, endemic hemoptysis).	Second intermediate host (snail first intermediate host); no multiplication of pathogen; man infested by ingestion of inadequately cooked host.
2	Flea, water (Cyclops spp)	Diphyllobothrium (subgenus Spirometra).	Sparganosis.	First intermediate host; no multiplication of pathogen; man infested by swallowing host Cyclops.
3	Flea, water (Cyclops, Diaptomus spp)	D. latum.	Diphyllobothriasis (fish tapeworm).	First intermediate host; no multiplication of pathogen; man infested by swallowing infested fish.
4	Flea, water (Cyclops spp).	Dracunculus medinensis.	Dracontiasis (Medina worm).	First intermediate host; no multiplication of pathogen; man infested by swallowing host Cyclops.
			Diplopoda (Millipedes)	
5	Fontaria virginiensis	Hymenolepis diminuta[1].	Rat tapeworm.	Pathogen develops from embryo to larva in arthropod hemocoel; definitive host infested by swallowing adult arthropod host.
6	Julus sp			
			Arachnida (Mites and Ticks)	
7	Mite, mouse (Allodermanyssus sanguineus)	Rickettsia akari.	Rickettsial pox.	Pathogen multiplies in mite; congenital transmission not demonstrated.
8	Mite, oribatid (Oribatidae)	Bertiella studeri, Inermicapsifer arvicanthidis.	Anoplocephaline tapeworm.	Pathogen matures from embryo to larva, without multiplication, in mite hemocoel. Man infested by swallowing host.
9	Mite, rat (Bdellonyssus bacoti)	Rickettsia typhi.	Murine typhus fever (experimental).	Pathogen multiplies in mite gut; experimental animal infected by mite bite.[2]
10	Mite, red chigger (Trombicula spp)	Rickettsia tsutsugamushi.	Scrub typhus (Japanese river fever).	Congenitally transmitted in mite.
11	Tick (Amblyomma spp, Dermacentor spp. Haemaphysalis spp, Hyalomma sp, Ornithodoros spp, Rhipicephalus spp)	Rickettsia australis, R. conori, R. rickettsi.	Spotted fever.	Pathogen multiplies in wall of tick midgut; congenitally transmitted in tick.
12	Tick (Amblyomma americanum, Dermacentor spp); many other ticks	Pasteurella tularensis.	Tularemia.	Pathogen multiplies in tick gut and hemocoel; congenitally transmitted in some ticks.
13	Tick (Dermacentor andersoni, Haemaphysalis humeross, Rhipicephalus sanguineus)	Coxiella burneti.	Q fever[3], Rocky Mt. spotted fever, tularemia.	Pathogen multiplies in wall of tick midgut.
14	Tick (Ornithodoros spp)	Borrelia spp.	Enzootic-endemic relapsing fever.	Pathogen multiplies in tissues of tick outside gut.
			Insecta(True Insects)[4]	
15	Bug, cone nose (Panstrongylus, Triatoma spp)	Trypanosoma cruzi.	Chagas' disease.	Pathogen multiplies in bug midgut; infection by fresh bug feces in contact with mucous membranes or scarified skin.
16	Flea, cat (Ctenocephalides felis)	Dipylidium caninum.	Dog tapeworm.	Pathogen develops from embryo to larva in flea hemocoel; swallowing flea causes infestation.
17	Flea, dog (C. canis)			
18	Flea, human (Pulex irritans)			
19	Flea, rodent (Xenopsylla cheopis and egg); other rat fleas	Hymenolepis diminuta[1].	Rat tapeworm	Pathogen develops from embryo to larva in flea hemocoel; swallowing flea causes infection.
20	Flea (X. cheopis, possibly Pulex irritans)	Pasteurella pestis.	Plague.	Pathogen multiplies in flea gut.
21	Flea (X. cheopis); occasionally other fleas	Rickettsia typhi.	Murine typhus fever.	Pathogen multiplies in flea midgut epithelium; man infected by flea feces or crushed flea rubbed into skin.
22	Fly, horse (Chrysops, Tabanus spp)	Pasteurella tularensis.	Tularemia.	Mechanical transmission from mouth parts of fly to man fusually via food).
23	Fly, house (Musca domestica); and other spp of Muscidae	Salmonella typhosa, S. paratyphi A, other Salmonella and Shigella spp, Vibrio cholerae, other enteric diseases.	Typhoid and paratyphoid fevers, dysenteries, cholera.	Mechanical [5]filth-borne[6] transmission by setae, feet, regurgitation and defecation into food or drinking water.
24	Fly, mango (Chrysops spp)	Loa loa.	Loaiasis (filariasis).	Pathogen matures from embryo to larva without multiplication in fly tissues.
25		Bartonella bacilliformis.	Bartonellosis (Carrion's disease, Verruga peruana).	Pathogen multiplies in fly midgut.
26	Fly, sand (Phlebotomus spp)	Charon sp.	Sand-Fly fever.	Pathogen multiplies in fly tissues.
27		Leishmania donovani, L. tropica, L. brasiliensis.	Visceral and cutaneous leishmaniasis, mucocutaneous leishmaniasis.	Pathogen multiplies in fly midgut.
28	Fly, tsetse (Glossina spp)	Trypanosoma gambiense, T. rhodesiense	African trypanosomiasis.	Pathogen multiplies in midgut and salivary glands of fly.
29	Gnat (Culicoides spp)	Acanthocheilonema perstans, A. streptocerca, Mansonella ozzardi.	Acanthocheilonemiasis, Ozzard's filariasis.	Pathogen matures from embryo to larva, without multiplication in gnat tissues.
30	Gnat (Simulium spp), black flies, buffalo flies, coffee flies	Onchocerca volvulus.	Onchocerciasis (filariasis).	Mechanical transmission.
31	Gnat, eye (Hippelates pusio)	Various bacteria, etc.	Conjunctivitis, pink eye.	Mechanical transmission.

/1/ Hymenolepis diminuta not commonly regarded as pathogenic to man. /2/ Reported experimental transmission not confirmed, nor has rat mite ever been shown to transmit murine typhus to man. /3/ Ticks of negligible or no significance in actual transmission of Q fever in the United States, the usual mode of transmission being via the respiratory route. /4/ The ear wig (Anisolabis annulipes), dung beetles (many spp), roaches (Blattella and Periplaneta spp), and moth larvae (a few spp) are not included in the table, as they either transmit pathogens to man so rarely as to be medical curiosities, or they transmit parasites not generally regarded as pathogenic to man. /5/ Human infestation with the dog tapeworm in this manner extremely rare.

Part I: DISEASE VECTORS (Concluded)

Unless otherwise indicated in the right-hand column ("Relationship"), infection or infestation is transmitted to man when bitten by the arthropod vector or host.

	Vector	Etiologic Agent	Disease or Infestation	Arthropod-Pathogen-Infection Relationship
			Insecta (True Insects)[4] (concluded)	
32		Rickettsia prowazeki.	Epidemic typhus fever.	Pathogen multiplies in epithelium of louse midgut; man infected by feces, or crushing on skin.
33	Louse, body (Pediculus humanus)	Rickettsia quintana.	Trench fever.	Pathogen probably multiplies in lumen of louse midgut; man infected by feces, or crushing on skin.
34		Borrelia recurrentis.	Epidemic relapsing fever.	Pathogen multiplies in tissues of louse outside gut; man infected by crushing on skin.
35	Louse, dog (Trichodectes canis)	Dipylidium caninum.	Dog tapeworm.	Pathogen develops from embryo to larva, without multiplication in louse hemocoel; man possibly infested by swallowing louse.[5]
36	Mosquito (Aedes spp)	Charon evagatus.	Yellow fever.	
37	Mosquito (Aedes spp, Armigeres obturans)	Dengue virus.	Dengue.	Pathogen multiplies in mosquito tissues.
38	Mosquito (Aedes spp, Culex spp, Mansonia titilians)	Erro spp.	Certain encephalitides.	
39	Mosquito (Anopheles spp)	Plasmodium falciparum, P. malariae, P. ovale, P. vivax.	Malaria fever.	Pathogen completes sexual cycle, then multiplies by sporogony in mosquito.
40	Mosquito (Anopheles spp, Aedes spp, Culex spp)	Wuchereria bancrofti.	Bancroft's filariasis.	Pathogen matures from embryo to larva without multiplication in mosquito tissues.
41	Mosquito (Anopheles spp, Mansonia spp)	Wuchereria malayi.	Malayan filariasis.	

[4] The earwig (Anisolabis annulipes), dung beetles (many spp), roaches (Blattella and Periplaneta spp), and moth larvae (a few spp) are not included in the table, as they either transmit pathogens to man so rarely as to be medical curiosities, or they transmit parasites not generally regarded as pathogenic to man. [5] Human infestation with the dog tapeworm is this manner extremely rare.

Part II: AGENTS OF DIRECT INJURY

	Arthropod	Geographical Distribution	Reservoir or Source	Injury
			Chilopoda (Centipedes)	
1	Centipede (Scolopendra spp)	World-wide.	Hidden under various objects.	Envenomization.
			Arachnida (Mites, Ticks, Scorpions, Spiders)	
2	Mite, follicle (Demodex folliculorum)[1]	World-wide.	Mammals.	Mild pruritis; follicular mange.
3	Mite, cheese (Tyroglyphus spp)		Cheese, grain, cereals, fruits.	Dermatitis.
4	Mite, grain (Glycyphagus spp)			Intestinal scariasis, grocer's itch, tropical eosinophilia, dermatitis.
5	Mite, grain itch (Pyemotes ventricosus)		Grain, seeds, straw.	Dermatitis, pruritis.
6	Mite, harvest, or chigger (Eutrombicula spp)		Weeds, grass, scrub.	Dermatitis, sucking of tissue fluids, allergy to arthropod saliva.
7	Mite, itch (Sarcoptes scabiei)		Man.	Sarcoptic acariasis, scabies.
8	Scorpion (Centruroides, Buthus, Tityus spp)	Tropics.	Under well-protected objects.	Envenomization.
9	Spider, black widow (Latrodectus mactans, other spp)	World-wide.	Protected dark places, latrines.	Arachnidism, envenomization.
10	Tick (Dermacentor, Ornithodoros, Ixodes spp)	N. America, Africa, Europe.	Mammals.	Tick paralysis, poisons in tick saliva. Vector organisms causing Rocky Mt. spotted fever.
			Pentastomida (Tongueworms)	
11	Worm, tongue (Armillifer, Linguatula, Porocephalus spp)	World-wide.	Reptiles, birds, mammals.	Linguatulosis, porocephalosis, endoparasites of mouth, throat, lung.
			Insecta (True Insects)[2]	
12	Ant (Solenopsis)	World-wide.	Hives, nests.	Envenomization.
13	Bedbug (Cimex spp)		Dwellings, public conveyances.	Bites, allergic reactions to saliva of bedbug.
14	Botfly (Gasterophilus spp) larva		Horse.	Irritation of skin, mucous membranes, eyes.
15	Botfly, human (Dermatobia hominis), larva	S. America, W. Indies, tropical N. America.	Forests (eggs transported by certain mosquitoes, ticks, assassin bugs).	Burrows into exposed skin, causes painful furuncular skin lesions.
16	Botfly, sheep (Oestrus ovis), larva	World-wide.	Sheep.	Inflammation of eyes, nose, mouth, ears, sinuses; skin lesions.
17	Bug, assassin (Reduvius, Rasahus spp)	N. and S. America.	On plants, lights, house walls, under rocks.	Stinging bites, allergic reactions to saliva of bug.
18	Bug, conenose (Panstrongylus, Triatoma, Rhodnius spp)	World-wide.	Dwellings, dark hiding places, rodent harborages.	Allergic reactions to saliva of bug.
19	Chigoe or jigger, sand flea (Tunga penetrans)	S. America, W. Indies, Africa.	Homes, buildings, dwellings.	Cutaneous invasion, infection.
20	Flea, cat and dog (Ctenocephalides felis, C. canis)		Breeding areas or mammalian hosts.	Severe bites, allergic reactions, extreme annoyance. Vector of organisms causing epidemic typhus.
21	Flea, human (Pulex irritans)			
22	Flea, rat (Xenopsylla spp)			
23	Fly, black (Simulium spp)		Breeding areas.	Bites, allergic reactions.
24	Fly, deer (Chrysops spp), adult	World-wide.	Mammalian hosts.	Severe bites, allergic reactions, extreme annoyance.
25	Fly, heel, or cattle grub (Hypoderma spp), larva		Cattle.	Cutaneous or ocular invasion, furuncular lesions, pain, inflammation.
26	Fly, horse (Tabanus spp), adult		Mammalian hosts.	Severe bites, allergic reactions.
27	Fly, primary screwworm (Callitroga hominivorax), larva	W. Hemisphere (tropical, subtropical areas).	Adults: manure, meat, serous exudates; maggots: clean flesh.	Painful lesions of sinuses, ears, nose, anus, skin.

[1] Now believed to be of little importance in man. [2] Includes blister beetles and caterpillars of the genus Megalopyge which have stinging hairs.

	Vector	Geographical Distribution	Reservoir or Source	Injury
			Insects (True Insects)[1] (concluded)	
28	Fly, tumbu (Cordylobia anthropophaga), larva	Africa.	Dog, rat.	Cutaneous invasion, furuncular lesions, myiasis.
29	Fly (Wohlfahrtia spp)[3], larva	World-wide.	Various mammals.	Larvae penetrate tender areas of unbroken skin causing inflammation, furuncles.
30	Gadfly, Russian (Rhinoestrus purpureus), larva	N. Europe, Asia.	Host organisms.	Inflammation of eyes, nose, mouth, ears, sinuses and and skin by tissue penetration.
31	Honey-bee (Apis mellifera), wasp (Vespula spp); other bees	World-wide.	Hives, nests, flowers, tunnels.	Envenomization; allergy.
32	Louse, body (Pediculus humanus)		Man.	Pediculosis, skin irritation.
33	Louse, pubic or "crab" (Phthirus pubis)			
34	Maggot, Congo floor (Auchmeromyia luteola)	Africa.	Shady places, native huts.	Blood loss from bloodsucking larvae.
35	Mosquitoes (several genera)	World-wide.	Water, moist places.	Severe bites, secondary infections, allergic reactions. Vectors of organisms causing dengue, malaria and yellow fever.
36	Punkies (Culicoides spp)			Skin bites, eye irritation.

[2] Includes blister beetles and caterpillars of the genus Megalopyge which have stinging hairs. [3] A "flesh fly" of the order Sarcophagidae (Sarcophaga, Wohlfahrtia).

420. SELECTED ARTHROPOD PARASITES: MAMMALS, BIRDS

Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

	Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
			Arachnida (Mites, Ticks)			
1	Chigger (Eutrombicula alfreddugesi)	N. and S. America, West Indies.	Active forms, in grasses, shrubs, brambles.	Domestic and wild vertebrates.	External	Injection and toxins, sometimes death (small poultry); larvae are bloodsuckers.
2	Mite, chicken (Dermanyssus gallinae)	World-wide.	Eggs, non-feeding larvae, nymphs, adults in crevices of coops, roosts.	Poultry, other birds.	External	Decreased egg production, retarded growth, anemia, sometimes death. Vector of organisms causing spirochetosis, fowl cholera. Larvae, nymphs, adults bloodsuckers; nocturnal feeders only.
3	Mite, dog follicle (Demodex canis)		None.	Dog.	Eggs, nymphs, adults in hair follicles and sebaceous glands.	Follicle inflammation; mange; thickened skin, alopecia, emaciation, sometimes death.
4	Mite, ear (Otodectes cynotis)			Dog, cat, ferret.	All stages in ears; sometimes external.	Inflammation, ear scabs, head-shaking, scratching, droopy ears with discharge; epileptiform fits (severe cases).
5	Mite, itch (Sarcoptes scabiei)*			Most mammals, sheep (on head).	External; all active stages in skin tunnels.	Scratching, papules, vesicles, keratinization, alopecia, mange, emaciation, sometimes death.
6	Mite, northern fowl- (Bdellonyssus sylviarum)	United States, Canada, Mexico, Europe, S. Africa.	Eggs on feathers, in nests; other stages on surroundings.	Poultry, wild birds.	External; on body and feathers.	Skin lesions, egg reduction, retarded growth, anemia. Harbors neurotropic viruses. Larvae, nymphs, adults bloodsuckers.
7	Mite, scab (Psoroptes equi v. ovis)	World-wide.	None.	Sheep (other varieties on various domestic animals).	External; all active stages on skin around edge of lesions.	Scabbing; wool loss from biting, scratching; emaciation, sometimes death.
8	Mite, scaly leg (Knemidokoptes mutans)			Chicken, turkey, other domestic birds.	External; all active stages in tunnels between scales, feet, legs, neck, comb.	Inflammation, keratinization between scales of feet, legs; lameness.
9	Tick, American dog- (Dermacentor variabilis)	N. America.	Eggs on soil; unfed larvae, nymphs, adults on vegetation until host is found.	Principally dog; other domestic and wild animals, mainly attack rodents and other small animals.	External; on host only, while feeding. Larvae, nymphs mainly attack rodents and other small animals.	Skin damage. Vector of organisms causing bovine anaplasmosis, tularemia. Rocky Mt. spotted fever. Larvae, nymphs, adults bloodsuckers.
10	Tick, black-legged (Ixodes ricinus scapularis)	Europe, some other countries.	Eggs on soil; larvae, nymphs, adults on grass and shrubbery until host is found.	Principally dog; other domestic and wild animals, under tail of other animals. On host only while feeding.	External; adults on head, neck of dog; on flank, leg.	Anemia. Vector of cattle red water fever, louping-ill virus, tick-borne fever virus of sheep. Larvae, nymphs blood suckers in ear, eyelid, head, rarely body.
11	Tick, brown dog- (Rhipicephalus sanguineus)*	World-wide.	Active forms near habitat of dog.	Dog mainly; occasionally other animals.	External. Larvae, nymphs.	Vector of organisms causing canine paroplasmosis, cattle gall sickness, nymphs, adults bloodsuckers.
12	Tick, cattle (Boophilus annulatus)*	N. America.	Eggs on soil; unfed larvae on grass.	Principally ungulates; other animals.	External.	Damage to hide; reduction of milk output. Vector of organisms causing Texas cattle fever. Larvae, nymphs, adults blood suckers.
13	Tick, ear (Otobius megnini)*	United States, Mexico, S. America, S. Africa.	Eggs on ground, in cracks; adults and unattached larvae in out-buildings.	Domestic animals.	Inside ears.	Ear inflammation, anorexia, dullness, sometimes death. Larvae, nymphs bloodsuckers.

Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

	Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
			Arachnida (Mites, Ticks) (concluded)			
14	Tick, fowl (Argas persicus)	Warm and temperate semi-arid regions of world.	All stages in crevices, cracks of housing and under bark of trees.	Domestic fowl, occasionally wild birds.	External; on host only while feeding;	Anemia, leg weakness, egg reduction, occasionally death. Vector of organisms causing fowl spirochaetosis, spirolplasmosis. Nymphs, adults bloodsuckers.
15	Tick, lone star (Amblyomma americanum)*	North, Central, and South America.	Eggs in soil; unfed larvae, nymphs, adults on grass.	Cattle, dog, horse, goat, sheep, occasionally birds.	External, on host only while feeding	Damage to hide, milk reduction. Vector of organisms causing Rocky Mt. spotted fever, Q fever. Larvae, nymphs, adults bloodsuckers.
16	Tick, Rocky Mountain wood- (Dermacentor andersoni)*	Western N. America.	Eggs on soil.	Most mammals.	External, larvae, nymphs on most small animals; adults usually on larger animals during feeding periods.	Paralysis, particularly in sheep. Vector of organisms causing Rocky Mt. spotted fever, tularemia, equine encephalomyelitis, anaplasmosis. Larvae, nymphs, adults bloodsuckers.
			Pentastomida (Tongueworms)			
17	Worm, tongue (Linguatula serrata)	World-wide.	Eggs swallowed, hatched in alimentary tract of herbivores; larvae, nymphs develop in mesenteries.	Mammals, birds, reptiles.	Eggs expelled in respiratory tract; adults in nasal passages.	Severe irritation and blocking of nasal passages.
			Insecta (True Insects)			
18	Bedbug (Cimex lectularius)*	World-wide.	All stages in cracks, crevices, similar hiding places.	Domestic animals, poultry.	External.	Nymphs, adults bloodsuckers; irritate skin, cause welts.
19	Blowfly, black (Phormia regina)[1]		Pupae in soil; adults in pastures.	Sheep, other mammals.	Eggs in hair or wool; larvae in wounds; eggs and larvae also in carcasses.	Extension and infection of wounds, marring of wool, emaciation.
20	Botfly, horse (Gasterophilus intestinalis)[2]		Pupae in soil; adults attack animals only in daytime.	Ass, horse, mule, rarely other animals.	Eggs on foreleg fetlock hairs, larvae (maggots) in mouth, pharynx, stomach.	Extension and infection of wounds.
21	Botfly, human (Dermatobia hominis)*	S. America, West Indies, tropical N. America.	Eggs glued to other arthropods, and hatch when reach suitable host.	Dog, swine, mule, cattle, wild animals.	Larvae leave transport arthropod on contact with host; penetrate skin.	Boil-like skin lesions; reduced milk production, damage to hide, decreased growth rate.
22	Botfly, sheep (Oestrus ovis)		Pupae on ground; adults in warm corners, crevices.	Sheep, rarely goat.	Larvae in nasal cavities, sinuses.	Mucosal irritation, nasal discharge, emaciation, sometimes death.
23	Bug, cone nose (Triatoma sanguisuga)[3]		All stages commonly found in or close to rodent nests or habitats.	All domestic animals, poultry; wood rat normal host.		Nymphs and adults bloodsuckers, cause swelling, anemia.
24	Flea, cat (Ctenocephalides felis)*		Immature forms associated with nest or sleeping area of host.	Cat, dog, other animals.	External	Coat damaged from biting, scratching. C. canis and C. felis vectors of dog- and dwarf tapeworms, heart-worm, plague, epidemic typhus. Adults are bloodsuckers.
25	Flea, dog (C. canis)					
26	Flea, human (Pulex irritans)*		Adults on ground part of time.	Dog, swine, other animals.		
27	Flies, stickligth (Echidnophaga gallinacea)*	World-wide, especially warm climates.	Immature forms associated with nest or sleeping area of host.	Poultry, domestic animals, rodents.	External; skin, comb, wattles, around eyes and ears.	Anemia, sometimes death. Adults are bloodsuckers.
28	Fly, black (Simulium spp)[4]	World-wide in temperate to subarctic climates.	Immature forms on under sides of stones in moderate running streams.	All warm-blooded animals.	External; on bare parts of head, body, legs, under wings.	Vesicles, red swelling, anemia, toxemia, death. S. occidentale and S. slossonae are vectors of turkey leucocytozoan disease; some spp are vectors of oncho-cerciasis of man and cattle. Adults bloodsuckers.
29	Fly, black horse- (Tabanus atratus)	N. America.	Immature form s in leaves and mud in and near streams, ponds.	Most warm-blooded animals.	External.	Adults bloodsuckers during day; vector of organism s causing anaplasmosis.
30	Fly, deer (Chrysops discalis)	Western N. America.	Eggs near water; larvae in water; pupae in mud.	Principally horse, cattle.	External, mainly on underside of abdomen, neck, withers.	Vector of tularemia, surra. Adults bloodsuckers.
31	Fly, flesh (Wohlfahrtia vigil)*	N. America.	Pupae on ground; larvae in woods.	Rabbit, mink, guinea pig, young of domestic and wild animals.	Larvae in wounds.	Mild to extensive subcutaneous pustular lesions; occasionally death.
32	Fly, greenbottle (Phaenicia sericata)	World-wide, except S. America and Pacific Islands.	Adults free-living; deposit eggs on flesh, soiled wool; pupae in soil.	Sheep, goat, other animals.	Larvae on skin, in wounds.	Invasion of wounds, suppuration.
33	Fly, horn (Siphona irritans)	Europe, America.	Eggs, maggots in fresh dung; pupae in dung or soil.	Cattle, other animals.	External.	Weight loss; milk reduction. Adults bloodsuckers.
34	Fly, house (Musca domestica)	World-wide.	Immature forms in manure and decayed matter; adults in buildings.	Any larger animal with lesions or secretions.	External, adults accidently ingested by host.	Adults cause decreased productivity of livestock. Vector of several tapeworm species, mechanical vector of many bacterial and protozoan pathogens and helminth eggs

/1/ The blowfly (Chrysomyia chloropyga) of Africa is similar to the black blowfly in its parasitism of sheep. /2/ The nose botfly (Gasterophilus haemorrhoidalis) and throat botfly (G. nasalis) are similar in many respects to the horse botfly. /3/ Sixteen spp of Triatoma found in Western Hemisphere, some of which are as important and as widely distributed as T. sanguisuga. /4/ Other Simulium spp that are important blackfly pests of livestock are S. articum, S. occidentale, S. ornatum, S. vittalum.

420. SELECTED ARTHROPOD PARASITES: MAMMALS, BIRDS (Concluded)

Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

	Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
			Insecta (True Insects) (concluded)			
35	Fly, louse or tick; ked (Hippobosca equina, Melophagus ovinus)	Most parts of world.	Larvae retained in female until mature; pupae on wool and feathers.	Horse, cattle, dog, sheep and birds, occasionally goat.	External; pupae attached to wool or feathers.	Anemia; wool stained, damaged from rubbing. Adults bloodsuckers. H. equina is mechanical vector of anthrax.
36	Fly, primary screw-worm (Callitroga hominivorax)*5	W. Hemisphere (tropical, sub-tropical areas).	Pupae in soil; adults in pastures.	Obligatory parasite of warm-blooded animals including livestock, wild mammals, dog, cat.	Eggs deposited on edges of wounds.	In fect, extend wounds, prevent heal-ing, invariably kill untreated host.
37	Fly, sand (Phlebotomus papatasi)*	Mediterranean region, southern Europe, Asia.	Immature forms in dark moist places, manure.	Warm-blooded animals.		Swelling at site of bite; vector of organisms causing pappataci fever. Adults nocturnal blood-suckers.
38	Fly, stable (Stomoxys calcitrans)*	World-wide.	Immature forms in manure and other moist organic waste.	Most mammals and birds.	External.	Weight loss; milk reduction. Vec-tor of poultry tapeworms, filariae, spirucids; mechanical vector of sarra. Adults bloodsuckers.
39	Fly, tsetse (Glossina morsitans)*	Central Africa.	Larvae pass from female when ready to pupate in soil.	Cattle, other animals.		Vector of organisms causing cattle and horse nangana, sleeping sick-ness to man. Adults bloodsuckers.
40	Grub, common cattle-(Hypoderma lineatum)	Prevalent in America, Europe, India, N. Asia.	Pupae in soil; adults in pastures.	Cattle, rarely horse.	Eggs on hair of legs, body; larger larvae form tumor under skin of back.	Skin perforation, hide and flesh damage, milk reduction.
41	Grub, northern cattle-(H. bovis)					
42	Louse, cattle biting (Bovicola bovis)	N. America.	None.	Cattle.	External; eggs hairs; nymphs, adults feed on skin.	Reduced vigor, weight gains; irritation, scaly skin.
43	Louse, chicken body-(Menacanthus stramineus)	World-wide.		All domestic fowl.	External; nymphs, adults on skin around vent; eggs attached to feathers.	Scabbing of skin, wasting; loss in egg production.
44	Louse, chicken head-(Cuclotogaster heterographus)			Chicken, partridge.	External; nymphs, adults on skin and feathers of head, neck; eggs on feathers.	Unthriftiness.
45	Louse, dog biting (Trichodectes canis)	N. America.		Dog.	External; eggs on hair; nymphs and adults feed on skin.	Scaly skin from rubbing, scratching.
46	Louse, hog (Haematopinus suis)	World-wide.		Swine.	External; eggs on hair.	Dermatitis, skin sores, retarded growth. Nymphs, adults blood-suckers. Vector of organisms causing swine pox.
47	Louse, shaft (Menopon gallinae)			Chicken, duck, pigeon, turkey.	External; eggs, nymphs, adults feed on scales, scabs, feathers.	Scaling and scabbing.
48	Louse, short-nosed cattle- (Haematopinus eurysternus)[6]			Cattle.	External; eggs on shaft or at base of hairs.	Hair damage from rubbing; stunting; reduction of milk output. Nymphs, adults bloodsuckers.
49	Mosquito (Aedes dorsalis)*	N. America, Europe, northern Africa.	Immature forms in moist soil; eggs survive long periods of drying in soil.	Warm-blooded animals.	External.	Adult females bloodsuckers. Vec-tor of organisms causing equine encephalomyelitis.
50	Mosquito (Anopheles punctipennis)*	N. America.	Immature forms in streams, ponds of hilly country.		External, where hair or feathers are thinnest.	A. punctipennis is vector of organ-isms causing dog heartworm. C. quinquefasciatus is vector of or-ganisms causing avian malaria, fowl pox. Adult females bloodsuckers.
51	Mosquito, southern house- (Culex quinquefasciatus)*	World-wide from 60°N to 50°S latitudes.	Immature forms in stagnant water, ponds and ditches.	Warm-blooded animals, especially birds.		

/5/ Adult stage of the secondary screwworm fly (C. macellaria) resembles the primary screwworm fly in appearance, but differs from the latter in being a secondary invader (facultative parasite), and breeding in carcasses; the larvae occasionally infest wool or necrotic wounds. /6/ Also applies to the long-nosed cattle louse (Linognathus vituli).

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
			Crustacea	
1	Sowbug or pillbug (Porcellio laevis), [A, I]	World-wide.	Vegetables, ornamentals.	Chews roots, growths near ground.[1]
2	Sowbug (Cylisticus convexus), [A, I]		Greenhouse seedlings.	Chews tender roots.[2]
			Arachnida	
3	Mite, bulb (Rhizoglyphus echinopus), [A, I]	N. America, Europe, Asia.	Ornamental bulbs, onion.	Bores into bulbs.
4	Mite, clover (Bryobia praetiosa), [A, I]	N. America.	Trees, grasses, legumes.	Sucks plant juices.[2]
5	Mite, cyclamen (Steneotarsonemus pallidus), [A, I]	N. America, Europe.	Greenhouse ornamentals, straw-berry.	Sucks plant juices, distorts buds and leaves.
6	Mite, fig (Aceria ficus), [A, I]		Fig.	Sucks plant juices.
7	Mite, pear leaf blister (Eriophyes pyri), [A, I]	All pear-growing regions.	Pear, apple.	Sucking causes blisters underside of leaves.
8	Mite, 2-spotted spider- (Tetranychus telarius), [A, I]	U.S.A., Europe, Africa, Asia, Australia.	Cultivated plants.	Sucks plant juices, causing loss of vigor, dropping of leaves.[3]
9	Mite, spider (Tetranychus, other spp), [A, I]	World-wide.	Cultivated plants.	Sucks sap causing whitish blotches on plant tissues, webbing of leaves.[2]

/1/ Nocturnal feeder, dependent on moist conditions. /2/ Control with DDT spray or dust. /3/ Control with phosphate and other insecticides.

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
			Diplopoda	
10	Millipede, common (Julus beserui), [A,I]	World-wide.	Vegetables, ornamentals.	Chews young roots, stems.
11	Millipede (Orthomorpha spp), [A,I]		Young plants.	Chews young roots, stems.
			Symphyla	
12	Centipede, garden (Scutigerella immaculata), [A,I]	N. and S. America, Europe, Africa.	Garden plants, flowers.	Chews tender plants, rootlets.[4]
			Insecta	
13	Ant, cornfield (Lasius alienus americanus) [A]	U.S.A.	Corn.	Symbiotic with aphids attacking corn roots.
14	Aphid, apple (Aphis pomi), [A, N]	N. America.	Apple.	Causes wilting.[3, 5]
15	Aphid, cotton (A. gossypii), [A, N]	U.S.A.	Cotton, melons, other plants.	Causes shedding of leaves, fruit.
16	Aphid, green peach (Myzus persicae), [A, N]	Warm regions of world.	Many trees, shrubs.	Sucks sap from leaves, causing curling, distortion; honeydew excreted.
17	Aphid, pea (Macrosiphum pisi), [A, N]		Peas, clovers, alfalfa.	Transmits pea mosaic virus; sucks plant juices.[4, 3]
18	Aphid, woolly apple (Eriosoma lanigerum), [A, N]	N. and S. America, Europe, S. Africa, Asia, Australia.	Apple, pear, elm.	Sucks sap from roots, branches, causing deformed twigs, knotty roots, stunting.[5]
19	Appleworm or codling moth (Carpocapsa pomonella), [L]	All apple areas.	Apple, pear, walnut, others.	Burrows into fruit, destroying or reducing value.[2]
20	Armyworm (Pseudoletia unipuncta), [L]	World-wide.	Grains, grasses, some legumes.	Devours foliage.
21	Bagworm (Thyridopteryx ephemerae formis), [L]	Eastern U.S.A.	Cedar, other trees.	Devours foliage.[6]
22	Bee, leaf-cutter (Megachile latimanus), [A]	World-wide.	Various trees.	Cuts off leaf fragments for nests.[2]
23	Beetle, Black Hills (Dendroctonus ponderosae), [A, L]	Rocky Mountain regions.	Ponderosa, lodgepole, limber and white bark pines.	Bores into bark and cambial region; may girdle and kill tree.
24	Beetle, blister (Epicauta vittata), [A]	World-wide.	Potato, legumes.	Devours plants.[4]
25	Beetle, Colorado potato- (Leptinotarsa decemlineata), [A, L]	N. America, Europe.	Potato, tomato, tobacco, eggplant, solanaceous plants.	Devours leaves, terminal growth.[4]
26	Beetle, confused flour- (Tribolium confusum), [A, L][7]	World-wide.	Flour, grain products.	Infests and contaminates flour, mixes, bread.
27	Beetle, dried fruit (Carpophilus hemipterus), [L]		Dried fruit.	Destroys dried fruit.
28	Beetle, drugstore (Stegobium paniceum), [A, L]		Dried vegetables.	Destroys dried vegetables.
29	Beetle, Engelmann spruce (Dendroctonus engelmanii), [L]	Western U.S.A.	Engelmann spruce, Colorado blue spruce, lodgepole pine.	Bores into bark and cambial region; may girdle and kill tree.
30	Beetle, flea (Altica, Epitrix, Phyllotreta spp), [A, L][8]	World-wide.	Vegetable crops.	Adult holes leaves; larva often feeds on roots.
31	Beetle, grain (Caulophilus latinasus), [A, L]		Stored grain.	Destroys grain.
32	Beetle, green June- (Cotinis nitidal), [A, L]		Cultivated plants (sap, fruit juices).	Destroys certain fruits; larva feeds on roots.
33	Beetle, Japanese (Popillia japonica), [A, L][9]	Eastern U.S.A., Japan, China.	Fruit trees, ornamentals, vegetables, grasses.	Destroys turf, foliage, blossoms, fruit.[2]
34	Beetle, lesser grain borer (Rhyzopertha dominica), [A, L]		Grain flour, wood-pulp paper.	Destroys.
35	Beetle, Mexican bean- (Epilachna varivestis), [A, L]	U.S.A., Mexico.	Bean, soybean, cowpea, other legumes.	Devours leaves, pods, stems.[10]
36	Beetle, mountain pine (Dendroctonus monticolae), [A, L]	Western U.S.A.	Western, lodgepole, sugar, ponderosa, white bark, and limber pines.	Bores into bark and cambial region; may girdle and kill tree.
37	Beetle, rhinoceros (Dynastes tityus), [A]		Ash.	Shreds bark.
38	Beetle, saw-toothed grain- (Oryzaephilus surinamensis), [A, L]	World-wide.	Grain, grain products, dried fruit.	Infests and devours grain, grain products, dried fruit.
39	Beetle, smaller European elm bark- (Scolytus multistriatus), [A]		Elm.	Vector of Dutch elm disease fungus.
40	Beetle, snout, or plum curculio (Conotrachelus nenuphar), [A, L]	Eastern U.S.A., and Canada.	Plum, apple, peach, cherry, deciduous stone fruits.	Adult punctures; larva feeds within and destroys fruit.[5, 11]
41	Beetle, southern pine (Dendroctonus frontalis), [A, L]		Pine.	Bores into bark and cambial region; may girdle and kill tree.
42	Beetle, spotted cucumber- (Diabrotica undecimpunctata), [A, L]		Corn, cucurbits, weeds, grasses, other plants.	Larva feeds on roots, adult devours foliage.[12]
43	Beetle, striped cucumber- (Acalymma vittata), [A, L]	N. America.	Cucurbits.	Adult devours leaves, shoots, blossoms, damages fruit; larva attacks underground parts.[13]
44	Beetle, tobacco flea- (Epitrix hirtipennis), [A]	World-wide.	Tobacco.	Devours leaves especially of young plants.[2]
45	Beetle, tuber flea- (E. tuberis), [A, L]		Potato.	Adult devours foliage; larva feeds on roots, tubers.
46	Beetle, western pine (Dendroctonus brevicomis), [A, L]	Western U.S.A.	Ponderosa and coulter pines.	Kills pine trees.
47	Bollworm, cotton, or corn earworm. (Heliothis zea), [L]	World-wide.	Cotton, corn, tomato, alfalfa, other plants.	Bores into and feeds on bolls, ears, buds; stunts plants, reduces yield.[2]
48	Bollworm, pink (Pectinophora gossypiella), [L]	Southern U.S.A., S. America, Africa, Europe, Asia, Australia.	Cotton, okra, other malvaceous plants.	Bores into and feeds on squares and bolls, cutting fiber, reducing yield.
49	Borer, currant (Ramosis tulipiformis), [L]	N. America, Asia, Europe, Australia.	Currant, gooseberry, black elder, sumac.	Burrows through canes.

[2] Control with DDT spray or dust. [3] Control with phosphate and other insecticides. [4] Control by treating soil with DDT, chlordane. [5] Control with demeton, malathion, or nicotine sprays. [6] Remove bags by hand in winter; control with lead arsenate sprays. [7] Another important species is the red flour beetle (T. castaneum). [8] Overwinters as adult. [9] Other important June beetles belong to Melolontha, Polyphylla and Phyllophaga spp. [10] Control with malathion or rotenone dusts, sprays. [11] Control with dieldrin sprays. [12] Vector of (a) bacterial wilt of cucurbits, (b) virus of yellow disease of asters. [13] Vector of bacterial wilt of cucurbits; control with methoxychlor.

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
			Insecta (continued)	
50	Borer, flat-headed apple tree- (Chrysobothris femorata), [L]	U.S.A., Canadian fruit-growing areas.	Fruit trees, many shade trees.	Bores into trunk of weakened trees, branches, twigs; kills trees.[14]
51	Borer, peach tree (Sanninoidea exitiosa), [L]	All peach-growing areas.	Peach, other stone-fruit trees.	Bores in trunk at ground-level roots, girdles tree trunk, kills trees.[2]
52	Borer, round-headed apple tree- (Saperda candida), [L]	Eastern U.S.A., Canada.	Apple, pear, quince trees.	Bores into trunk.
53	Borer, squash vine (Melittia cucurbitae), [L]		Squash, pumpkin, cucumber, melons.	Bores into and may girdle vine.
54	Borer, sugar cane (Distraea saccharalis), [L]		Sugarcane, rice, corn, sorghums, wild grasses.	Causes dead hearts in young plants, dead tops in older plants, broken-over stalks, loss in weight and sucrose, injury to seed cane.
55	Budworm, spruce (Choristoneura fumiferana), [L]	Northern U.S.A., Canada.	Fir, spruce, hemlock, larch, white pine.	Causes partial to complete defoliation.
56	Bug, box elder (Leptocoris trivittatus), [A, I, N, L]		Box elder.	Sucks plant juices.
57	Bug, chinch (Blissus leucopterus), [A, N]	N. America.	Corn, grains, grasses.	Sap sucking causes wilting, death.[15]
58	Bug, 3-cornered alfalfa- (Spissistilus festinus), [A]	World-wide.	Alfalfa.	Stunting.[16]
59	Bug, harlequin cabbage- (Murgantia histrionica), [A, N]	Southern U.S.A., Mexico, C. America.	Cabbage, related crops, other plants.	Sap sucking causes plants to wilt, brown, and die.
60	Bug, lace (Corythucha arcuata)	World-wide.	Various trees, shrubs.	Speckling of leaves, stunting.[17]
61	Bug, squash (Anasa tristis), [A, N]	N. and C. America.	Squash, other cucurbits.	Sap sucking causes plants to wilt and die.
62	Bug, tarnished plant (Lygus lineolaris) [A, N]	N. America.	Many plants, trees.	Leaf sucking and toxins cause bud drop, distortion, stunting.[17]
63	Butterfly, monarch (Danaus plexippus), [L]		Milkweeds.	Feeds on host.
64	Cabbageworm, imported (Pieris rapae), [L]	N. America, Asia, Australia, Europe.	Cabbage, other crucifers.	Devours foliage.[16,17]
65	Cadelle (Tenebroides mauritanicus), [A, L]	World-wide.	Stored grain, grain products.	Infests, destroys grain, grain products.
66	Cankerworm, spring (Paleacrita vernata), [L]	Eastern U.S.A., Canada.	Fruit and shade trees.	Defoliates trees in spring.[2]
67	Caterpillar, eastern tent- (Malacosoma americanum), [L]	U.S.A. east of Rocky mountains.	Wildcherry, apple trees.	Defoliates trees in spring, early summer.[2]
68	Caterpillar, forest tent- (M. disstria), [L]	N. America.	Aspen, sugar maple, oak, birch, basswood, ash, gum, other trees.	Defoliates trees in summer.[2]
69	Chafer, rose (Macrodactylus subspinosus), [A]		Rose, grape, other bushes, vines.	Destroys blossoms, leaves, fruit.[2]
70	Cicada, periodical (Magicicada septendecium), [A]	Eastern and southern U.S.A.	Many deciduous trees, shrubs.	Oviposition punctures injure or kill twigs.[18]
71	Cornborer, European (Pyrausta nubilalis), [L]	Eastern U.S.A., Europe, Asia.	Corn main host; also many vegetables, weeds, ornamentals.	Bores into stalks, ears, causing breakage, reduced yield and quality.[19]
72	Cricket, field (Gryllus spp), [A, N]	N., C., and S. America.	Hay crops, cotton, linen.	Devours hay, plants, cotton, linen.[20]
73	Cricket, Mormon (Anabrus simplex), [A, N]	Western U.S.A.	Hay, grain, many plants.	Devours hay, grain, leaves, of plants.[20]
74	Cutworm, variegated (Peridroma margaritosa), [L]	World-wide.	Many plants.	Cuts down seedlings, transplants.[21]
75	Earwig, European (Forficula auricularia)	World-wide.	Growing plants, stored grain, decayed vegetation.	Chewing.
76	Flea, Lucerne (Smynthurus viridis), [A, I]	Europe, Australia.	Legumes.	Surface feeding causes scorching of leaves.
77	Fly, bulb (Lampetia equestris), [L]	Europe, N. America.	Narcissus, other bulbs.	Bores into bulbs.
78	Fly, carrot rust (Psila rosae), [L]	Europe, northern N. America.	Carrot, celery, umbelliferous plants.	Bores into and eats fibrous roots.[22]
79	Fly, frit (Oscinella frit), [L]	N. America, Europe, Asia.	Cereals, grasses.	Bores into stems, eats central shoots.
80	Fly, hessian (Phytophaga destructor), [L]	Europe, Asia, N. America, New Zealand.	Wheat, barley, rye.	Feeds on stems, causing breaking and stunting.[2]
81	Fly, Mediterranean fruit (Ceratitis capitata), [A, L]	Mediterranean region, Hawaii, S. Africa, S. America, western Australia.	Fruits, vegetables.	Adult makes egg punctures, larva burrows through fruit.[2,4]
82	Fly, vinegar fruit- or vinegar gnat (Drosophila melanogaster), [L]	World-wide.	Ripe or decaying fruit.	Larva breeds in ripe fruit.
83	Fruitworm, tomato (Heliothis sea) [L]		Tomato, corn, cotton, bean.	Feeds in fruit. (See Bollworm, cotton.)
84	Grasshopper, red-legged (Melanoplus femur-rubrum), [A, N]	World-wide.	Hay crops, range, pasture.	Devours hay, grasses, vegetation.[25]
85	Grasshopper, migratory- (M. mexicanus), [A, N]	Western N. America.	Crops, grasses.	Devours hay, grasses, legumes, cotton.[25]
86	Greenbug (Toxoptera graminum), [A, N]		Barley, oats, wheat, small grains.	Sap sucking causes leaves to wither, yellow; plants die.[26]
87	Hornworm, tobacco (Protoparce sexta), [L]	U.S.A., Canada.	Tobacco, tomato, eggplant, pepper, potato.	Devours foliage.[27]

[2] Control with DDT spray or dust. [10] Control with malathion or rotenone dusts, sprays. [13] Vector of bacterial wilt of cucurbits; control with methoxychlor. [14] Control by wrapping trunks of young trees with paper for first year. [15] Control with dieldrin barriers. [16] Control with methoxychlor. [17] Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. [18] Control with TEPP. [19] Control with DDT, Ryania, culture methods. [20] Control with poison bran bait containing fluosilicate, aldrin, chlordane, heptachlor, or toxaphene. [21] Control with toxaphene. [22] Control by treating soil with aldrin, dieldrin, etc. [23] Control by planting after "free fly" dates, and by planting resistant varieties. [24] Control with malathion bait or spray. [25] Control with aldrin, chlordane, heptachlor in dusts, sprays, baits. [26] Control with parathion spray. [27] Control with TDE, endrin.

Destructive stages of arthropods are indicated by the following symbols: associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
			Insecta (continued)	
88	Hornworm, tomato (Protoparce quinquemaculata), [L]	N. and S. America, Europe, Hawaii.	Tomato, tobacco, other solanaceae.	Devours foliage.
89	Jointworm, wheat (Harmolita tritici), [L]	Eastern and central U.S.A.	Wheat, some grasses.	Causes galls in wheat, breaking of stems.[28]
90	Katydid, broad-winged (Microcentrum rhombifolium), [A, N]	N. America.	Many broad-leaved trees, shrubs.	Chews leaves.
91	Leafhopper, beet (Circulifer tenellus), [A]		Sugar beet, bean.	Vector of curly top disease of beets (virus).
92	Leafhopper, potato (Empoasca fabae), [A, N]	N. and S. America.	Potato, alfalfa, bean, celery, other plants.	Leaf sucking causes wilting, drying of leaves, stunting.[2, 29]
93	Leafworm, cotton (Alabama argillacea), [L]	N. and S. America.	Cotton only.	Devours leaves.[2]
94	Locust, desert (Schistocerca gregaria), [A, N][30]	India, Iran, Arabia, N. Africa.	Many plants.	Chews leaves.
95	Louse, book (Liposcelis divinatorius), [A, I]	World-wide.	Cereals, vegetables.	Contaminates food, destroys book bindings.
96	Maggot, apple (Rhagoletis pomonella), [L]	North eastern and north central U.S.A.	Apple, blueberry.	Bores into and destroys fruit.[2]
97	Maggot, cabbage root (Hylemya brassicae), [L]	Northern U.S.A.	Cabbage, many other plants.	Bores into roots.[22]
98	Maggot, onion (H. antiqua), [L]	Europe, N. America.	Onion, garlic.	Mines out bulbs.[31]
99	Maggot, seed-corn (H. cilicrura), [L]		Corn, bean, other plants.	Devours seed.
100	Mealworm (Tenebrio molitor), [L]		Grain products and refuse.	Destroys grain, grain products.
101	Mealworm, dark (T. obscurus), [L]		Grain products and refuse.	Destroys grain, grain products.
102	Mealybug (Pseudococcus citri), [A, N]	Tropical and sub-tropical areas.	Citrus, ornamental plants.	Sap sucking causes plants to die back.[32]
103	Moth, Angumois grain (Sitotroga cerealella), [L]		Grain feed.	Destroys grain feed in storage.
104	Moth, codling (Carpocapsa pomonella), [L]	Apple growing regions of N. and S. America, Europe.	Apple, pear, quince, walnut, apricot, similar fruits. Asia, S. Africa, S. Australia.	Bores into and destroys fruit, or reduces its value.[2]
105	Moth, diamondback (Plutella maculipennis), [L]	World-wide.	All cruciferous plants.	Eats small holes in outer leaves.
106	Moth, European pine shoot- (Rhyacionia buoliana), [L]		Red, Scotch, mugho pines.	Kills buds, twigs.
107	Moth, grape berry (Paralobesia viteana), [L]	Eastern half U.S.A.	Grape.	Destroys berries.[2, 26]
108	Moth, gypsy (Porthetria dispar), [L]	Northeastern U.S.A., Europe, Asia.	Most deciduous and evergreen trees, shrubs.	Devours leaves.
109	Moth, Indian meal- (Plodia interpunctella), [L]	World-wide.	Grain, grain products, dried fruit, nuts.	Destroys and webs grain, grain products; infests fruit, nuts.
110	Moth, Mediterranean flour (Anagasta kuhniella), [L]		Mill products.	Destroys grain products.
111	Moth, Oriental fruit (Grapholitha molesta), [L]	N. America, Europe, Asia.	Peach, quince, apple.	Tunnels twigs, destroys fruit value.[2, 26]
112	Phylloxera, grape (Phylloxera vitifoliae), [A, N]	N. America, Europe.	Grape vines.	Root and leaf sucking causes galls, eventual death of vines.[33]
113	Pickleworm (Diaphania nitidalis), [L]	Southern U.S.A., West Indies.	Cucumber, squash, melons.	Feeds on surface, bores into flowers, buds, fruit, stalks, vines.
114	Psylla, pear (Psylla pyricola), [A, N]	Europe, U.S.A.	Pear.	Leaf sucking, causing leaf drop.[32, 26]
115	Roller, red-banded leaf- (Argyrotaenia velutiana), [L]	U.S.A.	Apple, peach, other trees, shrubs.	Devours foliage, scars fruit.
116	Sawfly, European spruce (Diprion hercyniae), [L]	Europe, northeastern U.S.A., Canada.	Spruce.	Devours leaves.
117	Sawfly, European wheat stem (Cephus pygmaeus), [L]	Northeastern U.S.A., Europe, Near East.	Wheat, rye, barley, timothy, other grasses.	Larva mines stems; causing breakage.
118	Sawfly, wheat stem (C. cinctus), [L]		Wheat, grasses.	Larva tunnels stems, cause breaking, reduced grain yield.
119	Scale, San Jose (Aspidiotus perniciosus), [A, N]	World-wide	Deciduous fruit trees, ornamentals.	Secreted toxins cause wilting, kill infested trees.[34]
120	Scale, soft brown (Coccus hesperidum), [A, N]	World-wide in greenhouses (subtropical	Citrus, ornamentals spp.	Sap sucking causes plants to die back.[32]
121	Silverfish (Lepisma saccharina), [A, I][35]	World-wide.	Starchy substances.	Devours book bindings, fabrics, wallpaper.
122	Slug, rose (Cladius isomerus), [L]	World-wide.	Rosebush.	Skeletonizes and causes browning of leaves.[36]
123	Spittlebug, meadow (Philaenus leucophthalmus), [N]	Eastern U.S.A.	Legumes, hay crops.	Sucks plant juices, causing wilting, stunting, reduced forage yield.[37]
124	Termite, eastern subterranean- (Reticulitermes flavipes), [A, N]	Eastern U.S.A.	Wood, dead wood, cellulose products.	Riddles, weakens, destroys wood and cellulose materials.[38]
125	Thrips, gladiolus (Taeniothrips simplex), [A, N]		Gladiolus, iris, lily.	Attacks flowers, foliage, causing silvering, browning, and distortion of leaves.
126	Thrips, onion (Thrips tabaci), [A, N, L]	N. and S. America, Europe, Asia, S. Africa, Australia.	Onion, bean, cabbage, tomato, cotton.	Sucks plant juices, causing leaves and buds to pucker and silver.[17]
127	Thrips, pear (Taeniothrips inconsequens), [A, N]		Pear, plum, prune.	Deforms buds, scars fruit, injures foliage.
128	Wasp, oak gall or apple (Amphibolips confluenta) [L]	World-wide.	Oak.	Causes galls on oak leaves.[39]

[27] Control with DDT spray or dust. [17] Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. [22] Control by treating soil with aldrin, dieldrin, etc. [26] Control with parathion spray. [28] Control by burning stubble, crop rotation. [29] Transmits hopperburn disease. [30] Has a migratory phase. [31] More serious under wet and cool conditions. [32] Honeydew is formed or excreted. [33] Control by using resistant root stocks. [34] Control by oil emulsion sprays in dormant stage, malathion sprays in summer. [35] Another species is the firebrat (Thermobia domestica). [36] Control by spraying undersides of leaves with malathion. [37] Control with lindane, methoxychlor sprays. [38] For protection of new structures, control by treating adjacent infested soil with DDT, chlordane, dieldrin. [39] Control by burning leaves in winter.

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS (Concluded)

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
		Insecta (concluded)		
129	Webworm, fall (Hyphantria cunea), [L]	U.S.A., southern Canada.	Broad leaf fruit, shade and nut trees.	Webs branches, devours foliage.[2]
130	Weevil, alfalfa (Hypera postica), [L]		Alfalfa.	Skeletonizes growing plant tips and leaves, making hay unpalatable as livestock feed.
131	Weevil, bean (Acanthoscelides obtectus), [L]	World-wide	Bean, pea, cowpea.	Devours inside of bean in field and storage.
132	Weevil, boll (Anthonomus grandis), [A, L]	Southern U.S.A., Mexico.	Cotton	Destroys buds, devours squares and bolls.[40]
133	Weevil, cowpea (Callosobruchus maculatus), [L]		Dried peas.	Destroys peas.
134	Weevil, pea (Bruchus pisorum), [L]	World-wide.	Pea.	Feeds within pea seeds.
135	Weevil, granary (Stophilus granarius), [A, L]		Grain, grain products.	Destroys grain.
136	Weevil, rice (S. oryza), [A, L]	World-wide.	Stored grains, cereal products.	Larva grows in kernels, destroys stored grain.
137	Weevil, sweetpotato (Cylas formicarius elegantulus), [A, L]	Southern U.S.A., other areas.	Sweetpotato, morning glory.	Adult feeds on leaves, vines, roots; larva in stems, roots, potato.
138	Weevil, white pine (Pissodes strobi), [L]	U.S.A., southern Canada.	Pine, Norway spruce.	Kills terminal growth; degrades lumber.
139	Whitefly, greenhouse (Trialeurodes vaporariorum), [N]	World-wide.	Most plants.	Leaf sucking causes wilting.[32]
140	Wireworm, Pacific Coast (Limonius canus), [L]	Rocky Mountains.	All vegetables and feed crops.	Destroys seeds, cuts underground stems, bores into roots, stems, tubers.
141	Wireworms (Agriotes, Limonius, Melanotus, Horistonotus spp), [L]	World-wide.	Truck, cereal and forage crops.	Devours or bores into roots, seeds.[41]
142	White grubs, or June beetles (Phyllophaga fusca, other Phyllophaga spp), [A, L]	"	Most plants.	Devours roots, underground parts; adult defoliates trees.[17]

/2/ Control with DDT spray or dust. /17/ Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. /32/ Honeydew is formed or excreted. /40/ Control by spraying or dusting with calcium arsenate, BHC, toxaphene, endrin, dieldrin, aldrin. /41/ Control corn wireworm (Melanotus sp) of U.S.A. by treating soil with DDT, chlordane, dieldrin, heptachlor.

422. SELECTED DISEASE VIRUSES: ANIMALS AND BACTERIA

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g.pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

	Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size mμ	Remarks
1	Abortion, equine	Tortor equae	Horse.	Fetus; fetal membranes.	Contact; lining from contaminated stalls.	Pregnant g.pig, hamster, equine fetus.	+	Fetal equine spleen; cat lung.	Passes Seitz.	Antig. related to equine influenza.
2	Abortion, sheep		Sheep.	Fetal membranes, uterine discharge.	Ingestion).	Cattle, mouse, g. pig.	+		(Over 400 [mf]).	Psittacosis group.
3	Adenoidal-pharyngeal-conjunctivitis		Man.	Pharynx; NP discharge; conjunctiva.	Conjunctival and NP discharges.			Human adenoid, tumor; monkey kidney.		Several antigenic types.
4	Anemia, equine, infectious	Trifur equorum.	Man, horse, donkey.	Blood, (all secretions, excretions).	Contact (ingestion, milk, flies).	Rabbit, swine, rat, mouse			11-5%(em).	

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitic, g. pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

	Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size $m\mu$	Remarks
5	Bacteriophages. Coli (T)		Escherichia coli, strain B.						15-150[sm].	4 antigenic groups, 7 phages.
6	Coli-dysentery group		E. coli, Shigella dysenteriae.						8-75[mf].	Several antigenic types, plaques.
7	Megatherium		Bacillus megatherium.			Mutants of Bacillus megatherium.			30-45[mf]; 30-37[c].	
8	Staphylococcus (Kreuger)		Micrococcus pyogenes var. aureus.						50-75[mf]; 60-70[c].	3 antigenic types, plaques.
9	Typhoid V (Q151)		Salmonella sctc typhosa.						Passes EK Seits.	Acts on V component of cells.
10	B virus	Scelus beta.	Monkey, (man[1]).	CNS, spleen, saliva.	Bite.	Rabbit, g. pig.	+	Monkey, kidney	125[mf].	Herpes-pseudorabies group.
11	Blue tongue	Tortor ovis.	Sheep, cattle.	Blood, all organs.	Midges (Culicoides).	Goat, hamster[2], mouse[2].	+		100-150[mf].	(Several antigenic types).
12	Borna disease	Erro bornemus.	Horse, sheep, cattle.	CNS, pancreas, saliva, nasal secretions.	Ingestion, contact.	Rabbit, g. pig, rat, mouse, monkey, chicken.			85-125[mf].	Reddish intranuclear inclusions--Type B.
13	Bwamba fever	Smith-burnis bwamba.	Man.	Blood.		Monkey, mouse.	+		75-113[mf].	
14	Chickenpox (varicella)	Briarcus varicellae.	Man.	Fluid, crusts of cutaneous lesions.	Air-borne, contact.			Human foreskin, embryo.	210-243[em].	Antig. related to herpes zoster.
15	Choriomeningitis, lymphocytic	Armillia cerebea.	Man, "house mouse."	Blood, CSF, urine, NP secretions, CNS.	(Urine of infected mice).	Mouse, g. pig, monkey.	+	Mouse brain, chick embryo.	37-55[c]; 40-60[mf].	
16	Colorado tick fever	Sabinia coloradensis.	Man, tick.	Blood.	Tick (Dermacentor).	Hamster, mouse.	+		35-50[mf].	
17	Common cold	Tarpeia mremens.	Man.	Respiratory tract.	NP discharges.	Chimpanzee, (man).		Human embryo lung.	30-70[mf].	
18	Contagious ecthyma	Hostia ecthymatis.	Man, sheep, goat.	Lesions of lips, eyelids, nose, mouth.	Contact, through abraded epith.				Passes V Berkefeld.	
19	Coxsackie	Daldorfia coxsackie.	Man, rabbit (cottontail).	Intestinal contents. Blood, pharynx, saliva, CNS.	Ingestion,	Mouse[2], hamster, monkey, chimpanzee.	+	Newborn, embryonic mouse[1].	17[em].	16 or more antigenic types.
20	Dengue	Sabinia sanburni.	Man, monkey.	Blood.	Mosquito (Aedes).	Mouse, hamster[2].	+		17-25[mf].	3 antigenic types.
21	Distemper, canine	Terpeia canis.	Dog, ferret, other carnivores.	Blood, secretions, excretions.	Contact, secretions, excretions.	Ferret, mouse[2], hamster.	+	Dog kidney.	20-22[em].	Classical, neurotrophic, hard pad types.
22	Distemper, feline	Tarpeia felis.	Cat, other Felidae.	All tissues, secretions, excretions.	Same as dog distemper.	(Cat).			Passes N Berkefeld.	Antig. diff. from dog distemper.
23	Durand disease		Man.	Blood, spleen, urine, CSF, intestinal contents.		Hamster, g.pig, dog, monkey, cat.	+	Chick embryo.	40-80[mf].	
24	Encephalitis, California	Rocaes hammonii.	(Man, horse, ground squirrel).		(Mosquito (Aedes, Culex)).	Mouse, cotton rat, hamster.	+		60-125[mf].	Antig. related to St. Louis encph. group.
25	Encephalitis, eastern equine	Erro tenbrockii.	Man, horse, birds.	CNS, blood, spleen.	Mosquito (Mansonia), (mites).	Mouse, many domestic and wild animals, birds.	+	Chick embryo, rct.	25[mf]; 40[c, em].	Antigenically distinct.
26	Encephalitis, Venezuelan equine	Erro venezuelensis.	Man, horse, mule.	CNS, blood, nasopharynx.	Mosquito (Aedes, Mansonelle).	Mouse, g.pig, rabbit, rat, dog, sheep, goat.	+	Mouse, human embryo.	Passes N Berkefeld.	
27	Encephalitis, western equine	Erro equinus.	Man, horse, mule, wild, domestic birds.	CNS, blood, spleen.	Mosquito (Culex), (mites).	Mouse, many domestic and wild animals.	+	Chick embryo.	25[mf]; 40[c, em].	Antigenically distinct.
28	Encephalitis, Japanese	Erro japonicus.	Man, horse, cattle, goat, (some wild birds).	CNS, blood.	Mosquito (Culex).	Mouse, hamster, monkey, domestic animals	+	Chick embryo, mouse, rabbit.	20-30[mf]; 10 or less [c] group.	Antig. related to St. Louis encph. agglut. RBC.
29	Encephalitis, Russian Far East	Erro all-vestris.	Man, squirrel, hedgehog.	CNS, blood, CSF, NP secretions, urine.	Tick (Ixodes persulcatus).	Mouse, hamster, monkey, sheep, wild birds.		Mouse, chick embryo, mouse tumor.	15-25[mf].	Antig. related to louping-ill; agglut. RBC.
30	Encephalitis, St. Louis	Erro sclerotus.	Man, chicken, other birds.	CNS, blood.	Mosquito, (Culex), (mites).	Mouse, monkey.	+	Mouse, chick embryo.	22-33[mf].	Antig. related to Japanese-West Nile group; agglut. RBC.
31	Encephalomyelitis, avian	Erro gallinae.	Chicken, pheasant.	Brain, liver, spleen.	Possibly by contact and through egg).	Young turkey, pigeon, duck.		Chick embryo.	26-30[mf].	
32	Encephalomyelitis, mouse, (Theiler)	Legio muris.	Mouse.	CNS, blood, intestinal contents.	Ingestion of feces.	Cotton rat, virus-free mice.	+	Chick, mouse embryo.	9-13[mf]; 15x115[em].	2 antigenic types; agglut. RBC.
33	Encephalomyocarditis		Monkey, monkey, goose, wild rodents.	CNS, blood.	(Mosquito (Taeniorhynchus).	Mouse, hamster, g. pig, monkey, cotton rat.		Mouse, chick embryo.	8-13[mf]; 25-30[em].	4 antig. types; agglut. RBC.
34	Exanthema subitum[5]	Morbillifex subitus.	Man.	Blood, upper resp. tract (feces).		Monkey.		(Human embryo).	Passes Seitz.	

/1/ Only by laboratory infection. /2/ Suckling. /3/ Also chick, human, monkey embryo. /4/ Spring-summer encephalitis. /5/ Roseola infantum.

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS= central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g. pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; N=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

	Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size mμ	Remarks
35	Fibroma, rabbit (Shope)	Molitor fibroma-tis.	Rabbit (cottontail), squirrel.	Subcutaneous nodules, skin, (blood, spleen).		Domestic rabbit, wood-chuck.	+	Rabbit testis (variant).	125-175 [mf].	Antig. related to myxoma, inflammatory variant.
36	Foot and mouth disease	Hostis pecoris.	Man, cattle, goat, sheep, swine.	Blood, saliva, milk, urine.	Contact, secretions, excretions, garbage.	Rabbit, g.pig, puppy, mouse, rat, baby chick.	+	G. pig, bovine epithelium.	8-12 [mf].	3 or more antigenic types, agglut. RBC.
37	Fowl plague	Tortor galli.	Domestic fowl, some wild birds.	Blood, secretions, excretions.	Ingestion.	Starling, canary, mouse, rat, rebbit, ferret.	+ and - pigeon	Chick embryo.	60-140[mf, c, em].	Antig. variants, agglut. RBC.
38	Fowl tumors: Chicken tumor I (Rous sarcoma)	Molitor tumoris.	Chicken.	Any mesodermal tissue, sometimes in blood.	(Early life: upper resp.-digestive tract.)	Domestic fowl (age limitations).	+	Chick embryo, chick.	100[mf]; 60-70[mf, dm].	Antig. related to lymphomatosis viruses.
39	Fowl leucosis (leukemia)	Trifur galli-narum.	Chicken.	Blood, viscera.		(Chicken, turkey, pheasant, guinea fowl).			20-120[mf]; 120[dm].	
40	Lymphomatosis (Marek paralysis)		Chicken.	Viscera, bones, eye tissues, neso-pharynx.	Through egg, in early life after hatching.	(Chicken).				
41	Gastroenteritis, human (Marcy)		Man.	Intestinal tract, resp. droplets.	Ingestion.	(Man).			Passes UF sintered glass.	Produces febrile disease.
42	Hepatitis, canine	Tortor vulpis,	Dog, fox, wolf, coyote, bear.	Blood, secretions, excretions.	Ingestion, secretions, excretions.	Ferret, other carnivores	+	Dog kidney.	Passes N Berkefeld.	
43	Hepatitis, human, (infectious)	Reedella trigints.	Man.	Blood, intestinal contents.	Ingestion of infected materials.	(Man).	+	(Rabbit, chick embryo).	Passes Seits.	Antig. distinct. Type A.
44	Hepatitis, human, (serum)	Reedella centum.	Man.	Blood.	Injection, contact with blood or derivatives.	(Man).	(+)		26 or less [mf].	Antig. distinct. Type B.
45	Hepatitis, mouse		Mouse	Blood, liver, urine, spleen, kidney, feces.		Mouse[2].		Mouse embryo.	130-180[mf].	Several antigenic types.
46	Herpes simplex	Scelus recurrens.	Man.	Skin, cornea, blood, mucoses, CNS.	(Contact).	Rabbit, mouse.	+	Rabbit, chick embryo.	100-150[mf].	Antig. related to B. pseudorabies.
47	Herpes zoster	Briareus scoticus.	Man.	Skin, sensory nerves, ganglia.		(Man)		Human skin.	210-250[em].	Antig. related to chickenpox.
48	Hog cholera	Tortor suis.	Swine.	Blood, all secretions, excretions.	Contact, secretions, excretions, garbage[3].	Rabbit, g.pig.		Swine testis, marrow, spleen.	5[em]; 27[em].	Antig., neurotrophic variants.
49	Inclusion conjunctivitis	Chlamyd-ozoon oculogenitale.	Man.	Conjunctiva, (cervix, urethra).	Contact, genitalis secretions.	Baboon.			250[dm].	
50	Influenza	Tarpeia alpha, beta, taylori.	Man.	Respiratory tract.	Contact, NP secretions.	Ferret, mouse.	+	Chick embryo, c, em. mouse tumor.	80-120[mf, c].	Antig. types A-C, agglut. RBC.
51	Influenza, equine	Tarpeia caballi.	Horse, mule.	Respiratory tract, blood, semen.	Inhalation, ingestion, contact.	(Horse).	+		Passes N Berkefeld.	Antig. related to equine abortion.
52	Influenza, swine	Tarpeia shopei.	Swine	Respiratory tract, blood.	Contact, secretions, ingestion of lungworm ova, larvae.	Ferret, mouse.	+		80-120[mf, c].	Antig. related to type A influenza. Virus and H. suis elicit clinical disease.
	Insect viruses:									Inclusion bodies:
53	Bergoldia calypta (Steinhaus)		Fir-shoot roller[7]	Blood cells, (fat tissue).	Oral, (egg).				50x262 [em].	capsular.
54	Morator nudus (Wasser)		Armyworm[8]		Oral.				25[em].	Inclusion bodies: none.
55	Polyhedral of Arctia villica		Cream spot tiger moth.	Hypodermis.	Oral, (egg).					Inclusion bodies: polyhedral.
56	Polyhedral of Diprion hercynise		European spruce sawfly.	Midgut, epithelium.	Oral, (egg).				50x250[em].	Inclusion bodies: polyhedral.
57	Silkworm jaundice	Borrelina bombycis.	Silkworm (Bombyx mori).	Fat, hypodermis, blood cells, (other tissues).	Oral, (egg).	(Gypsy moth; nun moth).			40x280[em].	Inclusion bodies: polyhedral.
58	Laryngotracheitis, avian, infectious	Tarpeia avium	Chicken, pheasant.	Larynx, trachea, bronchi.	Contact.		+ and - turkey.		45-83[mf]; 104[em].	
59	Louping ill	Erro scoticus.	Man, sheep.	CNS, blood, CSF (man).	Tick (Ixodes ricinus), contact (man).	Mouse, vole, swine, hamster, cattle, (horse).	+	Chick embryo.	15-20[mf]; 22-27[c].	Antig. related to Russian Far East virus.
60	Lumpy skin disease		Cattle.	Cutaneous nodules, l.n., blood, other tissues.			+		10-25[mf].	
61	Lymphogranuloma venereum	Miyagawa-nella lymphogranulomatis.	Man.	Genital lesion, CSF, inguinal l.n.	Direct contact.	Mouse, g.pig, monkey, (embryo, g. pig, mouse testis.)	+	Chick, mouse embryo, mouse testis.	300[dm]; 436[em].	Antig. related to psittacosis, produces toxin.
62	Measles (rubeola)	Morbillifex morbillorum.	Man.	Blood, skin, respiratory tract.	Contact, NP discharges.	Monkey.	+	Chick embryo, human, monkey kidney.	Passes Seits.	
63	Measles, German (rubella)	Morbillifex embryorum.	Man.	Blood, nasopharynx.	Contact, NP discharges.	(Man).			Less than 800[mf].	

/2/ Suckling. /5/ Roseola infantum. /6/ Raw. /7/ Cacoecia murinana. /8/ Cirphis unipuncta.

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	Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size mμ	Remarks
64	Meningo-pneumonitis		Man, (ferret)	Respiratory tract.		Mouse, ferret, monkey.	+		300-400[mf]; 354[em].	Antg. related to psittacosis; produces toxin.
65	Molluscum contagiosum	Molitor hominis.	Man.	Skin.	Direct contact.				190-250[em]	Agglut. RBC.
66	Mumps	Rabula inflans.	Man.	Salivary glands, blood, gonads, CSF.	Droplets of saliva.	Monkey, hamster.	+	Chick, mouse embryo.	90-135[mf]; 140-260 [em].	Agglut. RBC, produces hemolysin.
67	Myxoma-toxia, infectious	Borreliota myxo-matis.	Domestic, wild rabbit.	Skin, mucosa, blood.	Contact, arthropods (mechanical).	Domestic, wild rabbit.	+ (and duck.	Rabbit, chick embryo.	265±230; 75[em].	Antg. related to Fibroma (Shope).
68	Newcastle disease	Tortor furens.	Man, domestic fowl, some wild birds.	Blood, secretions, excretions (oviparis), lungs (calf).	Contact, garbage[b], (poultry scraps).	Common lab. animals, cattle, quail, sparrow[a].	+ (and duck).	Chick embryo.	80-100[mf].	Neural, pneumonic visceral strains, agglut. RBC.
69	Papilloma, rabbit (oral)	Molitor gingivalis.	Domestic rabbit.	Tongue.	(Suckling).	Wild rabbit.			Passes Berkefeld.	Differs antg. from papilloma (Shope).
70	Papilloma, rabbit (Shope	Molitor sylvilagi.	Rabbit (cottontail).	Skin.		Domestic rabbit, hamster.			22-35[mf]; 32-50[c].	Malignancy becomes carcinomatous.
71	Phlebotomus fever	Sabinia doerrii,	Man.	Blood.	Midge (Phlebotomus papatasi).	Man.			40-60[mf].	2 or more antig. types.
72	Pneumo-enteritis, bovine.	pappataci fever] Terpsia vitulae.	Calf.	Lungs, intestinal tract, blood.	(Contact, resp., intestinal discharges).	Mouse,			Passes N Berkefeld.	
73	Pneumonia of mice, virus		Mouse.	Lungs.	Contact, resp. excretions.	(Mouse).		Chick embryo.	100-150[mf].	Agglut. RBC.
74	Pneumonia, swine, virus		Swine.	Lungs.	Contact, resp. excretions.	(Swine).		Swine lung, kidney.	(Over 200[f].	
75	Pneumonitis	Miyagawa-nella felis.	Cat.	Respiratory tract.	Inhalston, resp. excretions.	Mouse, g. pig, rabbit, hamster.	+		423±161[em].	Antg. related psittacosis, produces toxin.
76	Pneumonitis, mouse (Nigg)		Mouse.	Lung.		(Mouse).	+		497[em].	Member of psittacosis group.
77	Pollomye-litis	Legio debilitans	Man.	CNS, intestinal tract, blood.		Chimpanzee, monkey, mouse, cotton rat, hamster.	+	Human, monkey.	28[em].	3 or more antig. types.
78	Pox, cow	Borreliota jenneri	Man, cattle.	Cutaneous lesions, teat, udder.	Contact.	Rabbit, g. pig.	+	Bovine fetus, skin.		Antig. related to vaccinia.
79	Pox, fowl	Borreliota avium.	Domestic fowl some wild birds.	Skin lesions, blood, mucosa, viscers.	Contact, (mosquito).		+ and duck; turkey.	Chick embryo.	125[mf, nl]. 264-322[em].	Differs antg. from vaccinia.
80	Pox, mouse (ectromelia)	Borreliota marmoracis	Mouse (domestic).	Skin, blood, liver, spleen.	Contact.	(Mouse).	+ (and duck).	Mouse embryo.	210-300[em].	Antg. related to vaccinia, agglut. RBC.
81	Pseudo-rabies	Formido suisekkyli (D'Aujesky's disease)	Cattle, sheep, swine, dog, cat, rat.	Cutaneous lesions, CNS, nasal secretions (swine).	Ingestion, contact.	Rabbit, g. pig, bat, monkey, mouse, hamster.[i]	+	Chick embryo, rabbit, g. pig.	90-100[em].	Antg. related to herpes.
82	Psittacosis (ornithosis, parrot fever)	Miyagawa-nella psittacci.	Man, psittacine birds, duck, chicken.	Lung, spleen, liver, resp. secretions, cloacal contents.	Inhalation, dried secretions droppings, contact.	Mouse, g. pig, monkey.	+	Chick embryo, mouse.	458[em].	Produces toxin.
83	Rabies	Formido inexorabilis.	All mammals.	CNS, salivary, lacrimal glands, kidney, pancreas, saliva.	Saliva, through broken epithelium.	Mammals, domestic fowl.	+ (and duck).	Rabbit, rat, mouse, chick embryo.	100-150[mf].	
84	Rift Valley fever	Reedelia vallis.	Man, sheep.	Blood, liver.	(Mosquito).	Cattle, goat, rat, monkey, mouse.		Chick embryo.	25-35[mf].	
85	Rinderpest	Tortor bovia.	Domestic animals, deer.	Blood, secretions, excretions.	Ingestion.	Rabbit, g. pig, Chinese pig.	+	Chick embryo.	Passes V Berkefeld.	
86	Smallpox variola	Briareus variolae (hominis).	Man, (monkey).	Lesions of skin, NP secretions, mucosa, blood.	Inhalation, secretions, scales.	Monkey, rabbit.	+		244-302[em].	Antig. related to vaccinia, agglut. RBC.
87	Stomatitis, vesicular	Hostis equinus	Man, horse	Lesions of feet, nose, udder.	Contact.	Rat, g. pig, mouse, monkey.	+	Mouse, g. pig embryo.	70-100[mf].	2 antig. types.
88	Trachoma	Chlamydozoon trachomatis.	Man, cattle, swine.	Conjunctiva, conjunctival exudate.	Contact, conjunctival exudate.	Ape, (man).	+		250[em].	
89	Vaccinia		(Cutaneous lesions in man, rabbit			Man, cattle, monkey, rabbit, mouse.	+ (and turtle).	Rabbit, g. pig, chick adult, embryo.	236-252[mf].	Antig. related to smallpox, agglut. RBC.
90	Vesicular exanthema, swine.	Hostis exanthematis.	cattle). Swine.	Lesions of nose, lip, mouth, feet, udder.	Contact, ingestion.	Horse, dog, hamster.		Swine embryo.	Passes N Berkefeld.	Several antig. types.
91	Wart, human [verrucae]	Molitor verrucae.	Man.	Cutaneous lesions.	(Contact).	(Man).			Passes N Berkefeld.	
92	West Nile	Erro nili.	Man, pigeon.	Blood.	(Mosquito).	Mouse, g. pig, monkey, hamster, (man).	+	Mouse, chick embryo.	20-30[mf].	Antig. related to St. Louis, agglut. RBC.
93	Yellow fever	Reedella evagatus.	Man, monkey, galago.	Blood, liver, CNS, spleen, Ln.	Mosquito (Aedes, possibly others).	Mouse, monkey, hedgehog.	+	Chick, mouse embryo.	18-19[c].	
94	Zika	Rocsea zika.	Man, monkey.	Blood.	(Isolated from Aedes mosquito).	Mouse.	+		18-26[mf].	

[6] Raw. [9] Also dog, fox, hedgehog (N. African). [10] Also ascites tumor cells (mm).

423. SELECTED RICKETTSIALES PARASITES: MAN AND DOMESTIC ANIMALS

	Organism	Host[1]	Disease	Method of Transmission
1	Anaplasma centrale	Cattle.	Benign anaplasmosis.	Tick to host.
2	A. marginale	Cattle.	Malignant anaplasmosis.	Tick to host.
3	A. ovis	Sheep, goats.	Ovine anaplasmosis.	Tick to host.
4	Bartonella bacilliformis	Man.	Oroya fever.	Sand fly to man.
5	Chlamydia trachomae	Man, ape, monkey.	Trachoma.	Contact.
6	C. oculogenitale	Man.	Inclusion blennorrhea, inclusion conjunctivitis, neonatal conjunctivitis.	Contact. Contaminated swimming pools.
7	Colesiota conjunctivae	Cattle, goat, sheep.	Ophthalmia.	
8	C. conjunctivae gallii	Birds.	Conjunctivitis, keratitis.	
9	Cowdria ruminantium	Goat, sheep, cattle.	"Heartwater."	Tick feces. Tick to host.
10	Coxiella burnetti	Man, cattle, sheep, goat.	Q fever.	Tick feces. Host to tick to host. Contact domestic animals. Inhalation infected dust. Contaminated milk.
11	Ehrlichia canis	Dog.	Canine rickettsiosis.	Tick to host.
12	E. bovis	Cattle.	Bovine rickettsiosis.	Tick to host.
13	E. ovina	Sheep.	Ovine rickettsiosis.	Presumed tick to host.
14	Eperythrozoon spp	Cattle, mouse, sheep, swine.	Eperythrozoonsis, anemia (parasite of erythrocyte).	Mouse louse to louse. Other arthropods suspected.
15	Grahamella talpae	Mole.	Grahamellosis, anemia (parasite of erythrocyte).	
16	Haemobartonella spp	Animals.	Haemobartonellosis, anemia (parasite of erythrocyte).	Flea to host.
17	Miyagawanella bronchopneumoniae	Mouse.	Mouse pneumonitis.	Contact.
18	M. felis	Cat.	Feline pneumonitis.	Contact.
19	M. lymphogranulomatosis	Man.	Lymphogranuloma venereum, lymphogranuloma inguinale.	Venereal contact.
20	M. ornithosis	Man, non-psittacine birds.	Ornithosis.	Similar to psittacosis (see below).
21	M. psittacii	Man, psittacine birds.	Psittacosis.	Inhalation infected dust. Bird to man, man to man.
22	Neorickettsia helminthoheca	Dog, fox, coyote.	"Salmon poisoning disease."	Intestinal parasitic fluke to man.
23	Rickettsia akari	Man.	Rickettsial pox.	Mite to man.
24	R. conorii	Man, dog as reservoir host.	Boutonneuse, Marseilles, Mediterranean fever.	Tick to man.
25	R. prowazekii	Man.	Epidemic typhus ("classic, Old World").	Louse feces. Man to louse to man.
26	R. quintana	Man.	Trench fever.	Body louse to man.
27	R. rickettsii	Man, rabbit, squirrel.	Rocky Mountain spotted fever.	Tick to man.
28	R. sibirica	Man, rodents.	Siberian tick typhus.	Tick to host.
29	R. tsutsugamushi	Man, monkey, rodents.	Tsutsugamushi fever, scrub typhus.	Mite to man.
30	R. typhi	Man, rodents.	Murine or endemic typhus	Flea feces. Rat to flea to man.
31	Ricolesia spp	Domestic ruminants and fowl.	Conjunctivitis.	Uncertain.

/1/ Animals listed in order of decreasing susceptibility.

424. SELECTED BACTERIAL PARASITES: MAN AND DOMESTIC ANIMALS

	Bacterial Organism	Host[1]	Disease	Method of Transmission
1	Actinobacillus lignieresi	Cattle, swine.	Actinobacillosis, "wooden tongue."	(Not definitely known.)
2	Actinomyces bovis	Cattle, swine, horse, man.	Actinomycosis, "lumpy jaw."	Buccal cavity. (Not definitely known.)
3	Bacillus anthracis	Man.	Anthrax.	Soil-borne. Contact, infected animal by-products, carcasses.
4		Cattle, sheep, horse, mule, swine.	Anthrax, "splenic fever," "charbon," "milzbrand."	Soil-borne. Infected feed, water, carcasses.
5	Borrelia anserina	Fowl.	Spirochetosis.	Arthropod vector. Feces-borne.
6	B. recurrentis	Man.	European relapsing fever.	Arthropod vector.
7	B. theileri	Cattle.	Spirochetosis.	Arthropod vector.
8	B. vincentii	Man.	Associated with Fusobacterium plauti-vincenti in Vincent's angina.	Buccal cavity. (Not definitely known.)
9	Brucella abortus	Cattle, man.	Brucellosis, undulant fever.	Ingestion infected milk. Contact.
10	B. melitensis	Goat, sheep, man.	Brucellosis, undulant fever.	Ingestion infected milk. Contact.
11	B. suis	Swine, man.	Brucellosis, undulant fever.	Contact.
12	Clostridium botulinum	Man, chicken, duck, horse, mule, cattle.	Botulism, food intoxication, limber-neck of fowl.	Ingestion of toxin in food.
13	C. feseri	Cattle.	Black leg, symptomatic anthrax.	Soil-borne. Wound infection.
14	C. hemolyticum	Cattle, sheep.	Icterohemoglobinuria.	Soil-borne. Contaminated feed, water.
15	C. novyi	Sheep.	Infectious necrotic hepatitis.	Soil-borne. Associated with liver fluke infection.
16	C. perfringens	Man.	Gas gangrene.	} Soil-borne. Wound infection.
17		Sheep.	Lamb dysentery, infectious enterotoxemia.	
18	C. septicum	Horse, sheep, cattle.	Malignant edema.	Soil-borne. Wound infection.
19	C. tetani	Man, sheep, cattle, goat, swine, horse.	Tetnus, lockjaw.	Soil-borne. Wound infection.
20	Corynebacterium diphtheriae	Man.	Diphtheria.	Carrier contact.
21	C. equi	Horse.	Pneumonia of foal.	Possible in utero.
22		Swine.	Submaxillary gland infection.	Contaminated soil, feed.
23	C. pseudotuberculosis	Sheep, goat.	Caseous lymphadenitis.	Contaminated feed, water.
24		Horse.	Ulcerative lymphangitis, pseudoglanders.	Contact, wound infection.
25		Cattle.	Pseudotuberculosis.	
26	C. pyogenes	Cattle, swine, sheep, goat.	Mastitis, purulent infections, arthritis.	Inhabitant mucous membranes. Contact, wound infection.
27	C. renale	Cattle, swine.	Pyelonephritis.	Inhabitant mucous membranes. (Not definitely known.)

/1/ Animals are listed in order of decreasing susceptibility.

424. SELECTED BACTERIAL PARASITES: MAN AND DOMESTIC ANIMALS (Concluded)

	Bacterial Organism	Host[1]	Disease	Method of Transmission
28	Diplococcus pneumoniae	Man.	Lobar pneumonia, meningitis, endocarditis.	Carrier contact.
29	Erysipelothrix rhusiopathiae	Man.	Erysipeloid.	Wound infection, contact infected carcasses.
30		Swine, sheep, fowl.	Erysipelas.	Feces-borne. Contaminated soil, feed, water.
31	Escherichia coli	Man, domestic animals.	Genito-urinary and intestinal infections.	Feces-borne. Normal flora of intestinal tract.
32	Fusobacterium plauti-vincenti	Man.	Associated with ulcerative stomatitis, Vincent's angina.	Buccal cavity. (Not definitely known.)
33	Hemophilus ducreyi	Man.	Soft chancre, chancroid.	Direct genital contact.
34	H. gallinarum	Chicken.	Infectious coryza.	Contact.
35	H. hemoglobinophilus	Dog.	Prepucial infection.	Direct sexual contact.
36	H. influenzae	Man.	Meningitis, obstructive respiratory infections.	Flora of respiratory tract. Droplet infection.
37	H. pertussis	Man.	Whooping cough.	Flora of respiratory tract. Droplet infection. Contact.
38	H. suis	Swine.	Associated with viral influenza.	Flora of respiratory tract. Droplet infection.
39	Klebsiella pneumoniae	Man, horse, cattle.	Respiratory infection; mastitis (cattle).	Contact. Flora of respiratory tract.
40	Leptospira canicola	Dog, man, swine, cattle.	Leptospirosis, Stuttgart's disease (dog).	Direct contact. Contamination of water by infected urine.
41	L. icterohemorrhagiae	Man, dog, swine, cattle, rodent.	Leptospirosis, Weil's disease.	Direct contact. Contamination of water by infected urine.
42	L. pomona	Cattle, swine, man.	Leptospirosis, swineherd's disease.	Direct contact. Contamination of water by infected urine.
43	Listeria monocytogenes	Man, domestic animals, fowl.	Listeriosis, meningoencephalitis.	(Not definitely known.)
44	Malleomyces mallei	Horse, man.	Glandera.	Contact. Contaminated feed, water.
45	Micrococcus pyogenes	Man, animals.	Abcesses, suppurative processes, food poisoning, septicemia.	Wound infection, ingestion contaminated food. Flora of skin and mucous membranes.
46	Moraxella bovis	Cattle.	Infectious keratitis.	Contact.
47	M. lacunata	Man.	Conjunctivitis.	(Not definitely known.)
48	Mycobacterium avium	Fowl, swine.	Tuberculosis.	Contact. Feces-borne. Contaminated feed, water.
49	M. leprae	Man.	Hansen's disease, leprosy.	(Not definitely known.)
50	M. paratuberculosis	Cattle, sheep.	Johne's disease.	Contact. Feces-borne. Contaminated feed, water.
51	M. tuberculosis var. bovis	Cattle, man, swine.	Tuberculosis.	Contact. Feces-borne. Contaminated feed, water. Milk-borne.
52	M. tuberculosis var. hominis	Man.	Tuberculosis.	Contact. Via respiratory or alimentary tract.
53	Neisseria catarrhalis	Man.	Catarrhal inflammations.	Flora of respiratory tract.
54	N. gonorrhoea	Man.	Gonorrhea.	Direct sexual contact.
55	N. meningitidis	Man.	Epidemic cerebrospinal meningitis.	Infection from respiratory tract of carrier.
56	Pasteurella multocida	Domestic animals, fowl, man.	Hemorrhagic septicemia, bronchiectasis, conjunctivitis.	Contact. Contaminated feed, water. Bites.
57	P. pestis	Man, rodent.	Bubonic and pneumonic plague.	Flea bite from infected rat. Droplet infection.
58	P. tularensis	Man, rodent.	Tularemia.	Contact contaminated carcasses. Insect vector.
59	Proteus vulgaris	Man.	Genito-urinary and intestinal (?) infection.	Feces-borne.
60	Pseudomonas aeruginosa	Man, animals.	Suppurative processes, septicemia, meningitis, genito-urinary infections.	Contaminated water, soil, feces, wound infection.
61	Salmonella enteritidis	Man, rodents.	Food poisoning, gastroenteritis.	Feces-borne.
62	S. gallinarum	Fowl.	Fowl typhoid.	Feces-borne. Ovarian transmission.
63	S. hirschfeldii	Man.	Paratyphoid fever.	Feces-borne.
64	S. paratyphi A	Man.	Paratyphoid fever.	Feces-borne.
65	S. paratyphi B	Man.	Paratyphoid fever.	Feces-borne.
66	S. pullorum	Fowl.	Pullorum disease, bacillary white diarrhea.	Feces-borne. Ovarian transmission.
67	S. typhimurium[2]	Man, rodents.	Food poisoning, gastroenteritis.	Feces-borne.
68	S. typhosa	Man.	Typhoid fever.	Feces-borne.
69	Shigella dysenteriae	Man.	Dysentery.	Feces-borne. Contaminated food, water. Contact. Fly-borne.
70	S. equuli	Horse.	Joint infection, nephritis.	Possible in utero.
71	Spherophorus necrophorus	Man (?).	Associated with ulcerative colitis(?).	
72		Horse.	Gangrenous dermatitis, "scratches."	Feces-borne. Associated with unsanitary conditions.
73		Cattle	Calf diphtheria.	
74		Sheep, goat	Lip-and-leg ulceration, ulcerative stomatitis, food rot.	
75		Swine.	Ulcerative stomatitis, enteritis.	
76	Spirillum minus	Man, rodents.	Rat-bite fever.	Rat bite.
77	Streptococcus agalactiae	Cattle.	Mastitis.	Contaminated milking equipment.
78	S. dysgalactiae	Cattle.	Mastitis.	Contaminated milking equipment.
79	S. equi	Horse.	Strangles.	Contact. Contaminated water, feed.
80	S. pyogenes	Man.	Scarlet fever, septic sore throat.	Direct personal contact, contaminated milk.
81	S. uberis	Cattle.	Mastitis.	Contaminated milking equipment.
82	Treponema pallidum	Man.	Syphilis.	Direct sexual contact.
83	Vibrio comma	Man.	Cholera.	Feces-borne from carrier. Contaminated food, water.
84	V. fetus	Cattle, sheep.	Vibrionic abortion, sterility.	Direct sexual contact.
85	V. jejuni	Cattle.	Dysentery.	Feces-borne. Contaminated feed and water.

/1/ Animals are listed in order of decreasing susceptibility. /2/ All warm-blooded animals.

	Host Plant and Pathogen	Disease
	Amaranth (Amaranthus viridis)	
1	Xanthomonas amaranthicola	Leaf spot.
	Apple (Pyrus malus)	
2	Erwinia amylovora	Fire blight.
3	Pseudomonas papulans	Blister spot.
4	P. syringae	Twig blight.
5	P. melophthora	Brown rot of fruit.
	Alfalfa (Medicago sativa)	
6	Corynebacterium insidiosum	Wilt and root rot.
7	Pseudomonas medicaginis	Stem blight.
	Ash (Fraxinus spp)	
8	Pseudomonas savastonoi var. fraxini	Canker.
	Banana (Musa paridisi)	
9	Pseudomonas celebensis	Blood disease.
10	P. solanacearum	Brown rot.
11	P. mashlacii	Bud rot and stunt.
	Barley (Hordeum vulgare)	
12	Pseudomonas coronafaciens	Leaf spot.
13	P. striafaciens	Stripe.
14	Xanthomonas translucens (f. sp)	Blight.
	Barberry (Berberis spp)	
15	Pseudomonas berberidis	Leaf spot.
	Bean (Phaseolus vulgaris)	
16	Corynebacterium flaccumfaciens	Wilt.
17	Pseudomonas phaseolicola	Halo blight.
18	P. stizolobii	Leaf spot.
19	P. syringae	Lilac blight.
20	P. viridiflava	Leaf spot and blight.
21	Xanthomonas phaseoli	Common blight.
22	X. phaseoli var. fuscans	Fuscous blight.
	Beet, sugar (Beta vulgaris)	
23	Pseudomonas wieringae	Ring rot.
24	Xanthomonas beticola	Bacterial pocket.
	Betle pepper (Piper betle)	
25	Pseudomonas betlis	Leaf blight.
26	Xanthomonas betlicola	Blight.
	Bindweed (Polygonum convolvulus)	
27	Pseudomonas polygoni	Leaf spot.
28	Xanthomonas ippalii	Wilt.
	Bowlesia (Bowlesia septentionalis	
29	Pseudomonas bowlesiae	Blight.
	Broom grass (Bromus spp)	
30	Pseudomonas coronafaciens var. atropurpurea	Leaf spot.
31	Xanthomonas translucens (f. sp)	Blight.
	Begonia, tuberous (Begonia spp and hybrids)	
32	Xanthomonas begoniae	Leaf spot.
	Broad bean (Vicia faba)	
33	Pseudomonas fabae	Blight.
34	P. vicine	Leaf and stem spot.
	Burdock (Arctium lappa)	
35	Xanthomonas nigromaculans	Black spot.
	Cabbage (Brassica oleracae var. capitata)	
36	Pseudomonas cichorii	Zonate spot.
37	Xanthomonas campestris	Black rot.
	Cactus (Opuntia spp)	
38	Erwinia sp	Soft rot.
	Cactus, giant (Carnegiea gigantea)	
39	Erwinia carnegieana	Rot or decay.
	Calendula (Calendula officinalis)	
40	Pseudomonas calendulae	Leaf and stem spot.
	Canna (Canna indica)	
41	Xanthomonas cannae	Blight.
	Carpet grass (Axonopus scoparius)	
42	Xanthomonas axonoperis	Blight.
	Carrrot (Daucus carota var. sativa)	
43	Erwinia carotovora	Soft rot.
44	Xanthomonas carotae	Leaf blight.
	Cassava (Manihot spp)	
45	Erwinia cassavae	Blight.
46	Xanthomonas cassavae	Leaf spot.
47	X. manihotis	Wilt and gummosis.
	Castor bean (Ricinus communis)	
48	Xanthomonas ricinicola	Leaf spot.
	Cauliflower (Brassica oleracese var. botrytis)	
49	Pseudomonas maculicola	Peppery spot.
	Celery (Apium graveolens)	
50	Pseudomonas spi	Leaf spot.
	Cereals and grasses	
51	Corynebacterium agropyri	Yellow gum disease.
52	C. rathayi	Yellow gum disease.
53	C. tritici	Yellow gum disease.
54	Pseudomonas alboprecipitans	Streak.
55	P. coronafaciens	Streak.
56	Xanthomonas translucens various f. sp	Blight.

	Host Plant and Pathogen	Disease
	Cherry, sweet (Prunus avium)	
57	Pseudomonas syringae	Gummosis and blight.
	Chicory, Witloof (Cichorium intybus)	
58	Pseudomonas marginalis	Rot.
	Chrysanthemum (Chrysanthemum morifolium)	
59	Erwinia chrysanthemi	Bacterial blight.
	Chestnut (Castanea spp)	
60	Pseudomonas castaneae	Bacterial blight.
	Citrus (Citrus spp)	
61	Erwinia citrimaculans	Fruit spot.
62	Pseudomonas syringae	Blast and black pit.
63	Xanthomonas bilvae	Shot hole and fruit canker.
64	X. citri	Canker.
	Clover (Trifolium spp)	
65	Pseudomonas radiciperda	Root rot.
66	P. stizolobii	Leaf spot.
67	P. syringae	Leaf spot.
	Cocklebur (Xanthium sp)	
68	Xanthomonas badrii	Blight.
	Corn (Zea maya)	
69	Bacterium stewartii	Wilt.
70	Erwinia dissolvens	Stock rot.
71	Pseudomonas desaiana	Stunking rot.
72	P. lapsa	Leaf and stock rot.
	Cosmos (Cosmos spp)	
73	Erwinia cosmovora	Fire blight.
	Cotton (Gossypium spp)	
74	Xanthomonas malvacearum	Angular leaf spot.
	Cowpea (Vigna sinensis)	
75	Pseudomonas syringae	Bacterial leaf spot.
76	Xanthomonas vignicola	Canker.
	Crucifers: cabbage, cauliflower, turnips, radish	
77	Xanthomonas campestris	Black rot.
78	X. vesicatoria var. raphani	Blight.
	Cucumber (Cucumis sativus)	
79	Pseudomonas lachrymans	Angular leaf spot.
	Cucurbits: cucumber, squash, cantaloupe	
80	Erwinia tracheiphila	Wilt.
81	Xanthomonas cucurbitae	Leaf spot.
	Cumin (Cuminum spp)	
82	Pseudomonas cumini	Blight.
	Currant (Ribes aureum)	
83	Pseudomonas ribicola	Leaf spot.
	Dandelion, Russian (Taraxacum kok-saghyz)	
84	Xanthomonas taraxaci	Leaf blight.
	Delphinium (Delphinium spp)	
85	Pseudomonas delphinii	Black spot.
	Dianthus, Carnations, pinks (Dianthus spp)	
86	Pseudomonas caryophylli	Root rot and wilt.
87	P. woodsii	Leaf spot.
88	Dieffenbachia (Dieffenbachia picta) Xanthomonas dieffenbachiae	Leaf spot.
89	Dysoxylum sectabile Pseudomonas dysoxyli	Leaf spot.
90	Elder (Sambucus edulis) Xanthomonas sambuci	Blight.
91	Elm (Ulmus spp) Erwinia nimipressuralis	Wetwood.
92	Pseudomonas lignicola	Black streak of wood.
93	Fern, bird's nest (Asplenium nidus) Pseudomonas asplenii	Leaf blight.
94	Filbert (Corylina spp) Pseudomonas coluraae	Leaf spot.
95	Xanthomonas corylina	Blight.
96	Fir, Douglas (Pseudotsuga taxifolia) Bacterium pseudotsugae	Gall.
97	Flax, New Zealand (Phormium tenax) Xanthomonas phormicola	Leaf stripe.
98	Fruit trees Agrobacterium rhizogenes	Hairy root.
99	A. tumefaciens	Crown gall.
	Geranium (Geranium spp)	
100	Xanthomonas geranii	Leaf spot.
101	X. pelargonii	Leaf spot.
102	Gardenia (Gardenia jasminoides) Pseudomonas gardiniae	Leaf spot.
103	Xanthomonas masculifolium-gardeniae	Leaf spot.
104	Ginseng (Panax quinquefolium) Pseudomonas panacis	Root and stem rot.
105	Gladiolus (Gladiolus spp) Pseudomonas marginata	Corm scab and leaf blight.
106	P. gladioli	Rot.
107	Xanthomonas gummisudans	Blight.
108	Glorybower (Clerodendron philomoides) Xanthomonas clerodendroni	Leaf spot.

	Host Plant and Pathogen	Disease
	Grape (Vitis vinifera)	
109	Erwinia vitivora	Dead arm.
110	Pseudomonas tumefaciens	Black knot.
111	Guayule (Parthenium argentatum) Erwinia carotovora f. sp parthenii	Root and stem rot.
112	Gypsophila (Gypsophila spp) Agrobacterium gypsophilae	Gall.
113	Henna (Lawsonia inermis) Xanthomonas lawsoniae	Leaf spot.
114	Heronbill (Erodium texanum) Pseudomonas erodii	Leaf spot.
115	Horseradish (Armoracia lapathifolia) Xanthomonas campestris var. armoraciae	Leaf spot.
116	Hyacinth (Hyacinthus orientalis) Xanthomonas hyacinthi	Yellow disease.
117	Erwinia spp	Soft rot.
118	Iris (Iris spp) Bacterium tardicrescens	Leaf blight.
119	Pseudomonas cichorii	Leaf blight.
120	P. iridicola	Leaf blight.
121	Ivy (Hedera helix) Xanthomonas hederae	Leaf spot.
122	Ivy, Japanese (Cissus japonica) Pseudomonas cissicola	Black spot.
123	Jimson weed (Datura spp) Xanthomonas hemmiana	Leaf spot.
124	Jute (Corchorus capsularis) Xanthomonas sakalae	Leaf spot.
125	Larkspur (Delphinium spp) Erwinia atroseptica	Black leg.
126	Laurel, California (Umbellularia californica) Pseudomonas lauracearum	Leaf spot.
127	Lespedeza (Lespedeza spp) Xanthomonas lespedezae	Wilt.
128	Lettuce (Lactuca sativa) Pseudomonas cichorii	Head rot.
129	P. marginalis	Marginal blight and rot.
130	P. viridilivida	Leaf spot and blight.
131	Xanthomonas vitians	Wilt and rot.
132	Lilac (Syringa vulgaris) Pseudomonas syringae	Blight.
133	Loquat (Eriobotrya japonica) Pseudomonas eriobotryae	Bud rot.
134	Lovage (Levisticum officinale) Pseudomonas levistica	Leaf blight.
135	Lupine (Lupinus spp) Erwinia lupini	Brown blight.
136	Xanthomonas phaseoli	Blight.
137	Mango (Mangifera indica) Bacillus subtilis	Soft rot.
138	Erwinia mangiferae	Leaf, stem and fruit blight.
139	Pseudomonas mangiferae-indicae	Leaf spot.
140	Maple (Acer spp) Pseudomonas aceris	Leaf spot.
141	Xanthomonas acernea	Leaf blight.
142	Marigold, African (Tagetes erecta) Pseudomonas tagetes	Leaf spot.
143	Morning glory (Ipomoea musicata) Xanthomonas uppalii	Blight.
144	Mulberry (Morus spp) Pseudomonas mori	Blight.
145	Millet, foxtail (Setaria italica) Pseudomonas setariae	Brown stripe.
146	Millet, broom corn (Panicum miliaceum) Pseudomonas panici-millacei	Leaf stripe.
147	Xanthomonas panici	Streak.
148	Mushroom (Agaricus campestris) Pseudomonas tolaasi	Spot.
149	Oat (Avena sativa) Pseudomonas coronafaciens	Halo blight.
150	P. coronafaciens var. atropurpurea	Purple spot.
151	Xanthomonas translucens (f. sp)	Blight.
152	Oleander (Nerium oleander) Pseudomonas tonelliana	Gall.
153	Olive (Oles spp) Pseudomonas savastanoi	Knott.
154	Onion (Allium cepa) Pseudomonas alliicola	Scale rot.
155	P. cepacia	Sour skin.
156	P. cichorii and P. marginalis	Soft rot.
157	Xanthomonas striaformans	Stripe.
158	Orchids Pseudomonas cattleyae	Leaf spot.
159	Palm, Washington (Washingtonia filifera) Pseudomonas washingtoniae	Leaf blight.
160	Pangara tree (Erythrina indica) Xanthomonas erythrinae	Leaf spot.
161	Passion-flower (Passiflora edulis) Pseudomonas passiflorae	Grease spot.
162	Pea (Pisum sativum) Pseudomonas pisi	Blight.
163	Pea, pigeon (Cajanus cajan) Xanthomonas cajani	Blight.
164	Peach (Prunus persica) Xanthomonas pruni	Spot of leaf and fruit.
165	Pear (Pyrus communis) Erwinia amylovora	Fire blight.
166	Pseudomonas syringae	Twig and blossom blight.
167	P. barkeri	Blossom blight.
168	P. nectarophila	Blossom blight
169	Pelargonium (Pelargonium spp) Pseudomonas erodii	Leaf spot.
170	Xanthomonas pelargonii	Leaf spot and stalk rot.
171	Pineapple (Ananas comosus) Erwinia ananas	Brown rot.
172	Pseudomonas ananas	Black rot.
173	Plantain (Plantago lanceolata) Xanthomonas plantaginis	Leaf spot.
174	Plum (Prunus spp) Pseudomonas mors-prunorum	Canker and stunt.
175	P. syringae	Blight and gummosis.
176	Xanthomonas pruni	Fruit and leaf spot.
177	Poinsettia (Euphorbia pulcherrima) Corynebacterium poinsettiae	Leaf and stem streak.
178	Xanthomonas poinsettiaecola	Leaf spot.
179	Poplar (Populus spp) Corynebacterium humiferum	Wet wood.
180	Pseudomonas rimasfaciens	Canker.
181	Poppy (Papaver spp) Pseudomonas papaveris	Black streak.
182	Xanthomonas papavericola	Black spot.
183	Potato (Solanum tuberosum) Bacillus spp	Storage rots.
184	Corynebacterium sepedonicum	Ring rot.
185	Erwinia atroseptica	Black leg.
186	Erwinia spp	Soft rot.
187	Streptomyces scabies	Scab.
188	Primrose (Primula spp) Pseudomonas primulae	Leaf spot.
189	Privet (Ligustrum japonicum) Pseudomonas ligutri	Leaf spot.
190	Solanaceae: eggplant, pepper, tomato, potato Pseudomonas solanacearum	Southern wilt or brown rot.
191	Rhubarb (Rheum rhaponticum) Erwinia rhapontici	Crown rot.
192	Rice (Oryza sativa) Xanthomonas oryzae	Leaf blotch.
193	X. kresek	Kresek disease.
194	Rose-mallow (Hibiscus spp) Pseudomonas syringae	Blight.
195	Rubus Agrobacterium rubi	Gall.
196	Erwinia amylovora f. sp rubi	Blight.
197	Senna (Cassia tora) Xanthomonas cassiae	Blight.
198	Sesbania (Sesbania sp) Xanthomonas sesbaniae	Leaf spot.
199	Sesame (Sesamum orientale) Pseudomonas sesami	Blight.
200	Snapdragon (Antirrhinum majus) Xanthomonas antirrhini	Leaf spot.
201	Sorghum (Sorghum spp) Pseudomonas andropogoni	Leaf blotch and streak.
202	Xanthomonas holcicola	Leaf spot.
203	Soybean (Glycine max) Pseudomonas glycenea	Leaf spot.
204	P. tabaci	Wildfire.
205	Xanthomonas phaseoli var sojensis	Pustule.
206	Stock (Matthiola incana) Pseudomonas matthiolae	Blight.
207	P. syringae	Blight.
208	Xanthomonas incanae	Blight.
209	Sugar cane (Saccharum officinarum) Bacterium albilineans	White streak and wilt.
210	Xanthomonas rubilineans	Red streak.
211	X. rubrisubalbicans	Mottled stripe.
212	X. vasculorum	Gummosis.
213	Sunflower (Helianthus spp) Pseudomonas helianthi	Leaf spot.
214	Sweet coltsfoot (Petasites japonica) Pseudomonas petasites	Blnck spot.

425. SELECTED BACTERIAL PARASITES: PLANTS (Concluded)

	Host Plant and Pathogen	Disease
	Tamarind (Tamarindus indica)	
215	Xanthomonas tamarindi	Leaf spot.
	Sweetpea and numerous other plants	
216	Corynebacterium fasciane	Fasciation.
	Teakwood (Tectona grandis)	
217	Pseudomonas tectonae	Seedling wilt.
218	Xanthomonas melhusii	Leaf spot.
	Tick-trefoil (Desmodium diffusum, D. gangeticum)	
219	Xanthomonas desmodii	Blight.
220	X. desmodii-gangetici	Blight.
	Tobacco (Nicotiana spp)	
221	Erwinia aroideae	Hollow stalk and barn rot.
222	Pseudomonas angulata	Angular leaf spot.
223	P. mellea	Rust.
224	P. polycolor	Leaf spot and wet rot.
225	P. pseudozoogleae	Black rust.
226	P. solanacearum	Granville disease.
227	P. tabaci	Wildfire.
228	Xanthomonas heterocease	Rust.
	Tomato (Lycopersicon esculentum)	
229	Corynebacterium michiganense	Canker and wilt.
230	Pseudomonas tomato	Bacterial speck.
231	Xanthomonas vesicatoria	Pustule.
	Trichrodesma zeylanicum	
232	Xanthomonas trichodesmae	Leaf spot.
	Tung-oil tree (Aleurites fordii)	
233	Pseudomonas aleuritidis	Angular leaf spot.
	Unicorn-plant (Martynia louisiana)	
234	Pseudomonas martyniae	Blight.
	Vegetables (fleshy), plants of tuberous and fleshy roots	
235	Erwinia aroideae	Soft rots.
236	E. atrosepticа	Soft rots.
237	E. carotovora	Soft rots.
238	E. chrysanthemi	Soft rots.
	Velvet bean (Stizolobium deeringianum)	
239	Pseudomonas stizolobii	Leaf spot.
240	Xanthomonas stizolobicola	Blight.
241	Vetch, milk (Astragalus sp) Pseudomonas astragali	Black spot.
242	Viburnum (Viburnum spp) Pseudomonas viburni	Leaf spot.
243	Walnut (Juglans spp) Xanthomonas juglandis	Blight.
	Wheat (Triticum aestivum)	
244	Pseudomonas atrofaciens	Basal glume rot.
245	Xanthomonas translucens f. sp undulosa	Black chaff.
	Willow (Salix spp)	
246	Erwinia salicis	Blight.
247	Pseudomonas saliciperda	Blight.
248	Winter cress (Barbarea vulgaris) Xanthomonas barbareae	Leaf blight.
249	Wisteria, Japanese (Milletia floribunda) Erwinia milletiae	Galls.
250	Zinnia (Zinnia elegans) Xanthomonas nigromaculans f. sp zinniae	Angular leaf spot.
	Numerous plants	
251	Agrobacterium tumefaciens	Crown gall.
252	Corynebacterium fascians	Fasciation.
253	Erwinia amylovora	Fire blight of Rosaceae.
254	E. aroideae	Soft rot.
255	E. atrosepticа	Soft rot.
256	E. carotovora	Soft rot.
257	E. chrysanthemi	Soft rot.
258	Pseudomonas solanacearum	Brown rot.
259	P. syringae	Blight.

426. SELECTED FUNGAL PARASITES: FIELD, FRUIT, VEGETABLE CROPS

	Host Plant and Pathogen	Disease
	Field Crops: Cereals	
	Barley (Hordeum vulgare)	
1	Erysiphe graminis	Powdery mildew.
2	Gibberella zeae	Fusarium blight, scab.
3	Helminthosporium gramineum	Stripe disease.
4	H. sativum	Spot blotch, root rot, foot rot, kernel blight.
5	Puccinia graminis, P. tritici	Stem rust.
6	P. hordei	Leaf rust.
7	Pyrenophora teres	Net blotch.
8	Rhynchosporium secalis	Scald.
9	Typhula itoana	Snow mold.
10	Ustilago hordei	Covered smut.
11	U. nigra	Black or semi-loose smut.
12	U. nuda	Loose smut.
	Corn (Zea maye)	
13	Cochliobolus heterostrophus	Southern leaf blight, seedling blight.
14	Diplodia zeae, D. macrospora	Stalk rot, dry ear rot.
15	Gibberella fujikuroi	Pink ear rot, seedling blight.
16	G. zeae	Stalk rot, red ear rot, seedling blight, root rot.
17	Helminthosporium carbonum	Northern leaf spot, charred ear, seedling blight.
18	H. turcicum	Northern leaf blight, seedling blight.
19	Physalospora zeae	Gray ear rot.
20	Puccinia sorghi	Rust.
21	Sclerospora graminicola	Downy mildew.
22	Ustilago maydis	Smut.
	Oats (Avena sativa)	
23	Leptosphaeria avenaria	Black stem.
24	Puccinia coronata avenae	Crown rust.
25	P. graminis avenae	Stem rust.
26	Ustilago avenae	Loose smut.
27	U. kolleri	Covered smut.
	Rice (Oryza sativa)	
28	Cercospora oryzae	Cercospora spot.
29	Cochliobolus miyabeanus	Helminthosporium blight.
	Rye (Secale cereale)	
30	Claviceps purpurea	Ergot.
31	Erysiphe graminis	Powdery mildew.
32	Gibberella zeae	Fusarium blight, scab.
33	Puccinia graminis secalis	Stem rust.
34	P. rubigo-vera secalis	Leaf rust.
35	Urocystis occulta	Stem smut.

	Host Plant and Pathogen	Disease
	Field Crops: Cereals (concluded)	
	Sorghum (Sorghum spp)	
36	Ascochyta sorghina	Rough spot.
37	Cercospora sorghina	Gray leaf spot.
38	Colletotrichum graminicola	Anthracnose.
39	Gloeocercospora sorghi	Zonate leaf spot.
40	Helminthosporium sorghicola	Target spot.
41	H. turcicum	Leaf blight.
42	Macrophomina phaseolina	Charcoal or stalk rot.
43	Periconia circinata	Milo disease, root rot.
44	Ramulispora sorghi	Sooty stripe.
45	Sphacelotheca cruenta	Loose kernel smut.
46	S. sorghi	Covered kernel smut.
	Wheat (Triticum aestivum)	
47	Erysiphe graminis tritici	Powdery mildew.
48	Gibberella zeae	Fusarium blight or scab.
49	Helminthosporium sativum	Crown rot, root rot.
50	Leptosphaeria nodorum	Glume blotch, node canker.
51	Ophiobolus graminis	Take-all.
52	Puccinia glumarum	Stripe rust.
53	P. graminis tritici	Stem rust.
54	P. rubigo-vera tritici	Leaf rust.
55	Septoria tritici	Leaf blotch.
56	Tilletia brevifaciens	Dwarf bunt.
57	T. caries, T. foetida	Bunt or stinking smut.
58	Urocystis tritici	Flag smut.
59	Ustilago tritici	Loose smut.
	Field Crops: Legumes	
	Alfalfa (Medicago sativa)	
60	Ascochyta medicaginis	Spring black stem.
61	Leptosphaeria pratensis	Leaf spot, root rot, crown rot.
62	Peronospora trifoliorum	Downy mildew.
63	Pseudopeziza medicaginis	Common leaf spot.
64	P. jonesii	Yellow leaf blotch.
65	Sclerotinia trifoliorum	Crown rot, root rot.
66	Uromyces striatus medicaginis	Rust.
67	Urophlyctis alfalfae	Crown wart.
	Clover (Trifolium spp)	
68	Colletotrichum trifolii	Southern anthracnose.
69	Cymadothea trifolii	Sooty blotch (red, white and alsike clover).
70	Erysiphe polygoni	Powdery mildew (red clover).
71	Kabatiella caulivora	Northern anthracnose (crimson and red clover).
72	Phoma trifolii	Spring black stem (red clover).
73	Pseudoplea trifolii	Leaf spot.

	Host Plant and Pathogen	Disease
	Field Crops: Legumes (concluded)	
	Clover (Trifolium spp) (concluded)	
74	Sclerotinia trifoliorum	Root rot, crown rot.
75	Uromyces trifolii	Rust.
	Lespedeza spp	
76	Microsphaera diffusa	Powdery mildew.
	Soybean (Glycine soja)	
77	Cephalosporium gregatum	Brown stem rot.
78	Cercospora sojina	Frog-eye leaf spot.
79	Colletotrichum truncatum	Anthracnose.
80	Corynespora cassiicola	Target spot.
81	Diaporthe phaseolorum batatis	Stem canker.
82	D. phaseolorum sojae	Pod and stem blight.
83	Fusarium oxysporum trachephilum	Fusarium wilt.
84	Glomerella glycines	Anthracnose.
85	Macrophomina phaseoli	Ashy stem blight.
86	Pellicularia rolfsii	Southern wilt.
87	Peronospora manshurica	Downy mildew.
88	Phyllosticta sojicola	Leaf spot.
89	Phymatotrichum omnivorium	Texas root rot.
90	Sclerotinia sclerotiorum	Stem rot.
91	Septoria glycines	Brown spot.
	Sweetclover (Melilotus alba)	
92	Ascochyta spp	Leaf, stem, and pod blight.
93	Cercospora zebrina	Leaf spot.
94	Leptosphaeria pratensis	Leaf spot, crown rot, root rot.
95	Mycosphaerella davisii	Leaf spot.
96	M. lethalis	Black stem.
97	Phytophthora cactorum	Root rot.
98	Pseudopeziza medicaginis	Common leaf spot.
	Field Crops: Miscellaneous	
	Cotton (Gossypium spp)	
99	Fusarium oxysporum vasinfectum	Fusarium wilt.
100	Glomerella gossypii	Anthracnose.
101	Pellicularia filamentosa	"Soreshin" seedling stem canker.
102	Phymatotrichum omnivorium	Root rot.
103	Puccinia stakmanii	Rust.
104	Verticillium albo-atrum	Wilt.
	Flax (Linum usitatissimum)	
105	Colletotrichum lini	Anthracnose.
106	Fusarium oxysporum lini	Fusarium wilt.
107	Melampsora lini	Rust.
108	Mycosphaerella linorum	Pasmo disease.
	Peanut (Arachis hypogaea)	
109	Macrophomina phaseoli	Seedling blight.
110	Mycosphaerella arachidicola	Early leaf spot.
111	Pellicularia filamentosa	Dry rot.
112	P. rolfsii	Southern blight.
	Sugar cane (Saccharum officinarum)	
113	Helminthosporium sacchari	Eyespot.
114	Physalospora tucumanensis	Red rot.
	Peppermint, spearmint (Mentha spp)	
115	Puccinia menthae	Rust.
116	Verticillium albo-atrum	Verticillium wilt.
	Tobacco (Nicotiana tabacum)	
117	Cercospora nicotianae	Frog-eye leaf spot.
118	Fusarium oxysporum[1]	Fusarium wilt.
119	Macrophomina phaseoli	Charcoal rot.
120	Pellicularia filamentosa	Stem canker.
121	Peronospora tabacina	Blue mold.
122	Phytophthora parasitica[1]	Black shank.
123	Thielaviopsis basicola	Black rot.
	Fruit Crops	
	Apple (Pyrus malus)	
124	Clitocybe tabescens	Root rot.
125	Corticium galactinum	White root rot.
126	Gloeodes pomigena	Sooty blotch.
127	Glomerella cingulata	Bitter rot of fruit, stem canker.
128	Gymnosporangium juniperi virginianae	Rust.
129	Phyllosticta solitaria	Blotch, leaf spot, canker.
130	Podosphaera leucotricha	Powdery mildew.
131	Venturia inaequalis	Scab.
132	Xylaria mali	Black root rot.
	Apricot (Prunus armeniaca)	
133	Armillaria mellea	Root rot.
134	Corneum carpophilum	Coryneum blight.
135	Monilinia fructicola	Brown rot (ripe fruit)
136	M. laxa	Brown rot (green and ripe fruit), blossom and twig blight.

	Host Plant and Pathogen	Disease
	Fruit Crops (continued)	
	Avocado (Persea americana)	
137	Botryosphaeria ribis chromogena	Branch canker, fruit rot.
138	Cercospora purpurea	Cercospora spot or blotch.
139	Colletotrichum gloeosporioides	Anthracnose or black spot.
140	Diplodia theobromae	Stem-end rot.
141	Phomopsis sp	Stem-end rot.
142	Phytophthora cinnamomi	Phytophthora root rot.
143	Sphaceloma perseae	Scab (fruit and foliage).
144	Verticillium albo-atrum	Verticillium wilt.
	Blackberry (Rubus spp)	
145	Cercosporella rubi	Double blossom.
146	Elsinoë veneta	Anthracnose.
147	Kuehneola uredinis	Yellow leaf and cane rust.
148	Septoria rubi	Leaf and cane spot.
149	Verticillium albo-atrum	Verticillium wilt.
	Blueberry (Vaccinium spp)	
150	Botrytis cinerea	Blossom, fruit and twig blight.
151	Dothichiza caroliniana	Leaf spot.
152	Microsphaera alni vaccinii	Powdery mildew.
153	Monilinia vaccinii corymbosi	Mummy berry.
154	Physalospora corticis	Stem canker.
	Cherry (Prunus spp)	
155	Botrytis cinerea	Gray mold.
156	Coccomyces hiemalis	Leaf spot.
157	Monilinia fructicola	Brown rot, blossom blight.
158	M. laxa	European brown rot, blossom and twig blight.
159	Podosphaera oxyacanthae	Powdery mildew.
	Citrus (Citrus spp)	
160	Clitocybe tabescens	Root rot.
161	Diaporthe citri	Melanose, stem-end rot.
162	Diplodia natalensis	Twig and branch dieback, stem-end rot.
163	Elsinoë fawcetti	Scab.
164	Glomerella cingulata	Wilbertip, anthracnose.
165	Phytophthora citrophthora	Foot rot, brown rot.
	Cranberry (Vaccinium spp)	
166	Acanthorhynchus vaccinii	Blotch rot of berries.
167	Diplodia vaccinii	Twig blight.
168	Glomerella cingulata vaccinii	Bitter rot, leaf spot.
169	Guignardia vaccinii	Early rot, scald, blast.
170	Sporonema oxycocci	Leaf spot, berry rot.
	Fig (Ficus carica)	
171	Glomerella cingulata	Anthracnose.
172	Physopella fici	Rust.
173	Rhizoctonia microsclerotia	Leaf blight, web blight.
	Grape (Vitis spp)	
174	Cryptosporella viticola	Dead arm.
175	Elsinoë ampelina	Anthracnose.
176	Guignardia bidwellii	Black rot.
177	Plasmopara viticola	Downy mildew.
178	Uncinula necator	Powdery mildew.
	Olive (Olea europaea)	
179	Armillaria mellea	Root rot.
180	Asterina oleina	Black leaf spot.
181	Cycloconium oleaginum	Leaf spot.
182	Gloeosporium olivarum	Anthracnose.
183	Phymatotrichum omnivorum	Root rot.
	Peach (Prunus persica)	
184	Armillaria mellea	Root rot.
185	Clitocybe tabescens	Root rot.
186	Coryneum carpophilum	Blight, shot-hole.
187	Glomerella cingulata	Ripe rot, twig blight.
188	Monilinia fructicola	Brown rot, twig canker.
189	Taphrina deformans	Leaf curl.
	Pear (Pyrus communis)	
190	Botrytis cinerea	Gray mold.
191	Clitocybe tabescens	Root rot.
192	Neofabraea malicorticis	Black spot canker.
193	N. perennans	Perennial canker.
194	Podosphaera leucotricha	Powdery mildew.
195	Venturia pyrina	Scab.
	Plum (Prunus domestica)	
196	Armillaria mellea	Root rot.
197	Monilinia fructicola	Brown rot, blossom blight.
198	M. laxa	European brown rot, blossom and twig blight.
	Raspberry (Rubus spp)	
199	Didymella applanata	Spur blight.
200	Elsinoë veneta	Anthracnose.
201	Phragmidium rubi-idaei	Rust.

[1] Variety nicotianae.

426. SELECTED FUNGAL PARASITES: FIELD, FRUIT, VEGETABLE CROPS (Concluded)

	Host Plant and Pathogen	Disease
	Fruit Crops (concluded)	
	Raspberry (Rubus spp) (concluded)	
202	Septoria rubi	Leaf and cane spot.
	Strawberry (Fragaria chiloensis)	
203	Botrytis cinerea	Gray mold rot.
204	Dendrophoma obscurans	Leaf blight, stem-end rot.
205	Diplocarpon earliana	Leaf scorch.
206	Mycosphaerella fragariae	Leaf spot.
207	Phytophthora fragariae	Red stele.
	Nut Crops	
	Almond (Prunus amygdalus)	
208	Armillaria mellea	Root rot.
209	Coryneum carpophilum	Blight, shot-hole.
210	Monilinia fructicola	Peach brown rot.
211	M. laxa	Brown rot, blossom blight.
	Filbert (Corylus spp)	
212	Apiosporthe anomala	Twig blight, canker.
213	Armillaria mellea	Root rot.
214	Phyllactinia corylea	Powdery mildew.
	Pecan (Carya illinoensis)	
215	Cercospora fusca	Brown leaf spot.
216	Cladosporium effusum	Scab.
217	Gnomonia caryae pecanae	Liver spot.
218	G. nervisecda	Vein spot.
219	Mycosphaerella caryigena	Downy spot.
220	M. dendroides	Leaf blotch.
221	Phymatotrichum omnivorum	Cotton root rot.
	Walnut (Juglans regia)	
222	Armillaria mellea	Root rot.
223	Ascochyta juglandis	Ring spot.
224	Dothiorella gregaria	Dieback, black sap.
225	Exosporina fawcetti	Branch wilt, canker.
226	Gnomonia leptostyla	Leaf blotch.
227	Phytophthora cactorum	Crown rot.
	Vegetable Crops	
	Asparagus (Asparagus officinalis)	
228	Fusarium oxysporum asparagi	Wilt, root rot.
229	Puccinia asparagi	Rust.
	Bean (Phaseolus vulgaris)	
230	Colletotrichum lindemuthianum	Anthracnose.
231	Erysiphe polygoni	Powdery mildew.
232	Fusarium solani	Root rot.
233	Macrophomina phaseoli	Ashy stem blight, charcoal rot, leaf spot, root rot.
234	Uromyces phaseoli typica	Rust.
	Bean (Phaseolus lunatus macrocarpus)	
235	Colletotrichum truncatum	Stem anthracnose.
236	Diaporthe phaseolorum	Pod blight, leaf spot.
237	Macrophomina phaseolina	Ashy stem blight, charcoal rot, leaf spot, root rot.
238	Phytophthora phaseoli	Downy mildew.
	Beet (Beta vulgaris)	
239	Aphanomyces cochlioides	Black root, tip rot.
240	Cercospora beticola	Cercospora leaf spot.
241	Fusarium spp	Root rot, storage rot, wilt.
242	Peronospora schachtii	Downy mildew.
243	Pleospora betae	Leaf spot, root rot.
244	Uromyces betae	Rust.
	Carrot (Daucus carota)	
245	Alternaria dauci	Leaf blight.
246	A. radicina	Black rot.
247	Cercospora carotae	Blight, leaf spot.
	Celery (Apium graveolens dulce)	
248	Cercospora apii	Early blight.
249	Fusarium oxysporum apii	Fusarium yellows.
250	Septoria apii	Late blight (large spot).
251	S. apii-graveolentia	Late blight (small spot).

	Host Plant and Pathogen	Disease
	Vegetable Crops (concluded)	
	Crucifer (Brassica spp)[2]	
252	Alternaria brassicae	Gray leaf spot.
253	Fusarium oxysporum conglutinans	Yellows.
254	Mycosphaerella brassicicola	Ring spot.
255	Peronospora parasitica	Downy mildew.
256	Phoma lingam	Blackleg.
257	Phytophthora megasperma	Root rot of cabbage, cauliflower, and brussel sprouts.
258	Plasmodiophora brassicae	Clubroot.
	Cucurbit (Cucurbita spp)[3]	
259	Alternaria cucumerina	Leaf blight.
260	Cladosporum cucumerinum	Scab.
261	Colletotrichum lagenarium	Anthracnose (except squash).
262	Erysiphe cichoracearum	Powdery mildew.
263	Fusarium oxysporum melonis	Fusarium wilt (muskmelon).
264	F. oxysporum niveum	Fusarium wilt (watermelon).
265	F. solani cucurbitae	Fusarium root rot.
266	Mycosphaerella melonis	Black rot.
267	Pseudoperonospora cubensis	Downy mildew.
268	Verticillium albo-atrum	Verticillium wilt.
	Lettuce (Lactuca sativa)	
269	Botrytis cinerea	Gray mold.
270	Bremia lactucae	Downy mildew.
	Onion (Allium spp)	
271	Botrytis spp	Neck rot.
272	Peronospora destructor	Downy mildew.
273	Pyrenochaeta terrestris	Pink rot.
274	Urocystis cepulae	Smut.
	Pea (Pisum sativum)	
275	Aphanomyces euteiches	Root rot.
276	Ascochyta pinodella	Ascochyta foot rot.
277	A. pisi	Ascochyta leaf and pod spot.
278	Colletotrichum pisi	Anthracnose.
279	Erysiphe polygoni	Powdery mildew.
280	Fusarium oxysporum pisi, strain 1	Fusarium wilt.
281	F. oxysporum pisi, strain 2	Near-wilt.
282	F. solani pisi	Root rot.
283	Mycosphaerella pinodes	Mycosphaerella blight.
284	Peronospora viciae	Downy mildew.
	Pepper (Capsicum frutescens)	
285	Cercospora capsici	Frog-eye leaf spot.
286	Gloeosporium piperatum	Anthracnose.
287	Phytophthora capsici	Phytophthora blight.
	Potato (Solanum tuberosum)	
288	Alternaria solani	Early blight.
289	Fusarium spp	Wilt and tuber rot.
290	Phytophthora infestans	Late blight.
291	Streptomyces scabies	Common scab.
292	Verticillium albo-atrum	Verticillium wilt.
	Spinach (Spinacia oleracea)	
293	Albugo occidentalis	White rust.
294	Peronospora effusa	Downy mildew.
	Sweetpotato (Ipomoea batatas)	
295	Endoconidiophora fimbriata	Black rot.
296	Fusarium oxysporum batatas	Wilt, stem rot.
297	Monilochaetes infuscans	Scurf.
298	Pteudonus destructa	Foot rot.
299	Streptomyces ipomoea	Pox or soil rot.
	Tomato (Lycopersicon esculentum)	
300	Alternaria solani	Early blight.
301	Colletotrichum phomoides	Anthracnose.
302	Fusarium oxysporum lycopersici	Fusarium wilt.
303	Phoma destructiva	Phoma rot.
304	Phytophthora infestans	Late blight.
305	Septoria lycopersici	Leaf spot.
306	Stemphylium solani	Gray leaf spot.

[2/ Cabbage, cauliflower. [3/ Cucumber, muskmelon, squash, watermelon.

427. SELECTED FUNGAL PARASITES: FOREST TREES

	Host Plant and Pathogen	Disease
	Alaska-cedar (Chamaecyparis nootkatensis)	
1	Gymnosporangium nootkatense	Mountain ash-Alaska cedar rust.
	Alder (Alnus spp)	
2	Cytospora pulcherrima	Cytospora canker.
3	Didymosporella oregonensis	Didymosporella canker.
4	Erysiphe aggregata	Powdery mildew.
5	Melampsoridium alni	Leaf rust.
6	Taphrina amentorum	Leaf blister.
7	T. macrophylla	Yellow leaf blister.
8	T. occidentalis	Leaf blister.
9	T. robinsoniana	Leaf blister.
10	T. rugosa	Leaf blister.
	Arborvitae (Thuja orientalis)	
11	Coryneum berckmanii	Berckman's blight.
12	Gymnosporangium kernianum	Witches'-broom rust.

	Host Plant and Pathogen	Disease
	Arborvitae (Thuja orientalis) (concluded)	
13	Gymnosporangium nelsoni	Hawthorne-western juniper rust.
	Ash (Fraxinus spp)	
14	Armillaria mellea	Root rot.
15	Cytospora annularis	Cytospora canker.
16	Fomes fraxinophilus	White heart rot.
17	Marssonia fraxini	Leaf spot.
18	Mycosphaerella fraxinicola	Leaf spot.
19	Phymatotrichum omnivorum	Phymatotrichum root rot.
20	Polyporus hispidus	Spongy white rot.
21	Puccinia peridermiospora	Leaf rust.
	Ash, mountain (Sorbus americana)	
22	Gymnosporangium aurantiacum	Fusiforme rust of juniper.
23	G. juniperinum	Subglobose gall rust.
24	G. nidus-avis	Witches'-broom and spindle shaped gall rust.
	Basswood (Tilia spp)	
25	Collybia velutipes	Spongy white rot.
26	Pholiota squarrosa adiposa	Brown mottled rot.
27	Uncinula clintonii	Powdery mildew.
	Beech (Fagus grandifolia)	
28	Fomes fomentarius	White mottled rot.
29	F. igniarius nigricans	Heart rot.
30	Nectria coccinea faginata	Beech bark disease.
31	Phytophthora cactorum	Phytophthora blight.
32	Polyporus glomeratus	Light-brown spongy heart rot.
33	Poria obliqua	Canker.
	Birch (Betula spp)	
34	Fomes fomentarius	White mottled rot.
35	F. igniarius laevigatus	Heart rot and canker.
36	Melampsoridium betulinum	Leaf rust.
37	Nectria galligena	Nectria canker.
38	Pholiota squarrosa adiposa	Brown mottled rot.
39	Poria obliqua	Canker.
40	Stereum murrayi	Hot and canker.
41	Taphrina boycei, T. flava	Yellow leaf blister.
	Chestnut (Castanea dentata)	
42	Endothia parasitica	Chestnut blight.
43	Fistulina hepatica	Brown cubical rot.
44	Monochaetia desmazierii	Leaf spot.
45	Marssonia ochrolerica	Small leaf spot.
46	Polyporus sprague	Brown friable rot.
	Cypress, Arizona (Cupressus arizonica)	
47	Gymnosporangium cupressi	Fusiform gall rust.
	Cypress, monterey (Cupressus macrocarpa)	
48	Coryneum cardinale	Coryneum canker.
49	Polyporus basilaris	Brown cubical rot.
	Elm (Ulmus spp)	
50	Ceratostomella ulmi	Dutch elm disease.
51	Chalaropsis thielavioides	Chinese elm root rot.
52	Cytospora ambiens	Cytospora canker.
53	C. porinaldiibunda	Dieback.
54	Dothiorella ulmi	Dieback.
55	Gloeosporium ulmicolum	Leaf spot.
56	Gnomonia ulmea	Leaf spot.
57	Phlebopora ulmi	Elm leaf spot.
58	Phytophthora inflata	Pit canker.
59	Pleurotus ulmarius	Brown rot.
60	Sphaeropsis ulmicola	Canker.
61	Tuberculariа sp	Elm canker.
62	Uncinula macrocarpa	Powdery mildew.
63	Verticillium rhisophagum	Verticillium root disease.
64	Verticillium sp	Verticillium wilt.
	Fir (Abies spp)	
65	Adelopus gaumanni	Swiss needle cast.
66	Aleurodiscus amorphus	Aleurodiscus canker.
67	Armillaria mellea	Shoestring root rot.
68	Bifusella abietis, B. faullii	Needle cast.
69	Caecoma faullians	Needle rust.
70	Calyptospora goeppertiana	Needle rust.
71	Cephalosporium sp	Cephalosporium canker.
72	Corticium gelectinum	Corticium rot.
73	Cytospora abietis	Cytospora canker.
74	Dasyscypha resinaria	Dasyscypha canker.
75	Fomes amocus	Root and butt rot.
76	F. pini	Red ring rot.
77	F. pinicola	Brown cubical rot.
78	Hyalospora aspidiotus	Needle cast.
79	Hypodrma robustum	Needle cast.
80	Hypodermella abietis concoloris, H. mirabilis, H. nervata	Needle cast.
81	Lophodermium abietis, L. uncinatum	Needle cast.
	Fir (Abies spp) (concluded)	
82	Melampsora abieti-caprearum	Needle rot.
83	Melampsorella cerastii	Witches'-broom.
84	Melesia fructuosa, M. marginalis	Needle rust.
85	M. polypodophila	Needle-witches'-broom rust.
86	Peridermium holwayi, P. ornamentale, P. rugosum	Needle rust.
87	Phacidium infestans var. abietis	Needle blight.
88	Phomopsis boycei	Phomopsis canker.
89	Polyporus abietinus	White pitted sap rot.
90	P. balsameus	Brown butt rot.
91	P. dryadeus	White root rot.
92	P. schweinitzii	Root and butt rot.
93	Poria subacida	Butt rot.
94	Rehmellopsis balsamiae	Tip blight.
95	Scleroderris abieticola	Scleroderris canker.
96	Spicaria anomala	Brown stain of fir.
97	Stereum chailleti	Patchy rot.
98	S. sanguinolentum	Red heart rot.
99	Uredinopsis atkinosinii, U. ceratophora, U. longimucronata, U. macrosperma, U. mirabilis	Needle rust.
	Douglas-fir (Pseudotsuga mensiezii)	
100	Adelopus gaumanni	Needle cast.
101	Armillaria mellea	Shoestring root rot.
102	Botrytis douglasii	Gray mold blight.
103	Caliciopsis pinea	Caliciopsis canker.
104	Chondropodium pseudotsugae	Chondropodium canker.
105	Cytospora friesii	Cytospora canker.
106	Dasyscypha pseudotsugae	Dasyscypha canker.
107	Diplodia pinea	Top dieback.
108	Echinodontium tinctorium	Brown stringy rot.
109	Fomes applanatus	Mottle rot.
110	F. laricis	Brown trunk rot.
111	F. pini	Red ring rot.
112	F. pinicola	Brown cubical rot.
113	F. roseus	Yellow-brown tap rot.
114	Melampsora albertensis	Needle rust.
115	Phacidium infestans var. abietus	Needle blight.
116	Phomopsis lokoyae	Phomopsis canker.
117	P. pseudotsugae	Douglas-fir canker.
118	Polyporus schweinitzii	Root and butt rot.
119	Poria monticola	Brown cubical rot.
120	P. weirii	Laminated root rot.
121	Rhobdocline pseudosugae	Needle blight.
122	Sparassis radicata	Sparassis root rot.
	Hemlock, eastern (Tsuga canadensis)	
123	Fomes robustus-tsugina	White heart rot.
124	Ganoderma lucidum	White rot.
125	Keithia tsugae	Cedar leaf blight.
126	Melampsora abietis canadensis, M. farlowii	Needle rust.
127	Polyporus borealis	White mottled rot.
128	Puccinia strum hydrangeae, P. myrtilli	Needle rust.
129	Rosellinia herpotrichioides	Brown felt blight.
	Hemlock, western (Tsuga heterophylla)	
130	Armillaria mellea	Shoestring root rot.
131	Caecoma dubium	Needle rust.
132	Echinodontium tinctorium	Brown string rot.
133	Fomes annosus	Root and butt rot
134	F. pinicola	Brown cubical rot.
135	F. robustus-tsugina	White heart rot.
136	Ganoderma oregonense	White rot.
137	Uraecium holwayi	Needle rust.
	Hickory (Hicoria spp)	
138	Microstroma juglandis	Witches'-broom.
	Incense-cedar (Libocedrus decurrens)	
139	Gymnosporangium libocedri	Apple-incense cedar rust.
140	Polyporus amarus	Pocket dry rot.
	Juniper (Juniperus spp)	
141	Fomes juniperinus	Juniper pocket rot.
142	F. subrosseus	Brown pocket rot.
143	Gymnosporangium aurantiacum	Mountain ash, mountain juniper rust.
144	G. bermudianum	Juniper rust.
145	G. bethelii	Elongate gall rust of juniper.
146	G. clavariaeforme	Fusiform gall rust of juniper.
147	G. clavipes	Fusiform gall rust.
148	G. corniculans	Serviceberry, juniper rust.
149	G. davisii	Chokeberry-mountain juniper rust.
150	G. effusum	Fusiform gall rust.
151	G. exiguum	Hawthorne-alligator juniper rust.

	Host Plant and Pathogen	Disease
	Juniper (Juniperus spp) (concluded)	
152	Gymnosporangium externum	Portierianthus, fusiform gall rust of juniper.
153	G. floriformе	Hawthorne-juniper rust.
154	G. globosum	Hawthorne-cedar rust.
155	G. harnessianum	Servicеberry-western juniper rust.
156	G. inconspicuum	Servicеberry-Utah twig rust.
157	G. juniperi-virginianae	Apple cedar rust.
158	G. kernianum	Witches'-broom rust.
159	G. multiporum	Utah juniper rust.
160	G. nelsoni	Hawthorne-western juniper rust.
161	G. trachysorum	Fusiform gall rust of juniper.
162	G. tuberlatum	Globoid gall rust of mountain juniper.
163	G. vauquelinиae	Witches'-broom of vaulquelinia.
164	Keithia juniperi	Leaf blight.
165	Phomopsis juniperovora	Juniper blight.
	Larch (Larix europora)	
166	Dasyscypha willkommi	European larch canker.
167	Fomes pini	Red ring rot.
168	Melampsora bigelowii	Needle rust.
	Larch (Larix laricina)	
169	Hypodermella laricis	Needle cast.
170	Melampsora bigelowii	Needle rust.
171	M. medusae	Needle spot.
	Larch (Larix occidentalis)	
172	Fomes laricis	Brown trunk rot.
173	Hypodermella laricis	Needle cast.
174	Melampsora bigelowii, M. medusae	Needle rust.
175	Sparassis radicata	Sparassis root rot.
	Locust, black (Robinia pseudoacacia)	
176	Fomes rimosus	Yellow heart rot.
177	Fusicladium robiniae	Leaf spot.
178	Polyporus robiniophilus	White heart rot.
	Maple (Acer spp)	
179	Cristulariella depraedens	Leaf spot and wilt.
180	Daedalea unicolor	Rot and canker.
181	Daldinia concentrica	White rot.
182	Endoconidiophora virescens	Sapstreak.
183	Eutypella parasitica	Eutypella canker.
184	Fomes connatus	Butt rot.
185	F. igniarius nigricans	Heart rot.
186	Hydnum septentrionale	Soft spongy white rot.
187	Hymenochaete agglutinans	Hymenochaete canker.
188	Hypoxylon blakei	Hypoxylon canker.
189	Nectria cinnabarina	Nectria dieback.
190	N. galligena	Nectria canker.
191	Phleospora aceris	Leaf spot.
192	Phytophthora cactorum	Bleeding canker.
193	Polyporus glomeratus	Rot and canker.
194	Rhytisma acerinum	Tar spot.
195	Schizoxylon microsporum	Schizoxylon canker.
196	Stereum murrayi	Rot and canker.
197	Uncinula circinata	Powdery mildew.
198	Venturia acerina	Red-brown spot.
199	Verticillium albo-atrum	Verticillium wilt.
200	Xylaria digitata	Xylaria root rot.
	Oak (Quercus spp)	
201	Aleurodiscus oakesii	Smooth patch.
202	Armillaria mellea	Shoestring root rot.
203	Cronartium cerebrum	Globose gall rust.
204	C. fusiforme	Southern fusiform rust.
205	C. strobilinum	Pine cone rust.
206	Daedalea quercina	Brown cubical rot.
207	Endoconidiophora fagacearum	Oak wilt.
208	Fistulina hepatica	Brown cubical rot.
209	Fomes everhartii	White heart rot.
210	Gnomonia veneta	Anthracnose.
211	Hydnum erinaceus	White rot.
212	Morenoella quercina	Leaf spot.
213	Polyporus berkeleyi	White butt rot.
214	P. croceous	White pocket rot.
215	P. dryophilus	Piped rot.
216	P. frondosus	Butt rot.
217	P. hispidus	Heart rot and canker.
218	P. spraguei	White rot.
219	P. sulphureus	Brown cubical rot.
220	Sphaerotheca lanestris	Witches'-broom.
221	Sphaeropsis quercina	Sphaeropsis canker.
222	Stereum gausapatum	White mottled rot.
223	S. subpileatum	White pocket rot.
224	Strumella coryneoidea	Strumella canker.

	Host Plant and Pathogen	Disease
	Oak (Quercus spp) (concluded)	
225	Taphrina caerulescens	Oak leaf blister.
	Austrian pine (Pinus laricio-austriaca) [hard]	
226	Cronartium cerebrum	Eastern gall rust.
227	C. comandrae	Comandra blister rust.
228	Dothistroma pini	Needle blight.
	Jack pine (Pinus banksiana) [hard]	
229	Chilonectria cucurbitula	Burn blight.
230	Coleosporium solidaginis	Needle rust.
231	Cronartium cerebrum	Eastern gall rust.
232	C. comandrae	Comandra blister rust.
233	Hypodermella ampla, H. concolor, H. laricis	Needle cast.
234	Lenzites saepiaria	Brown cubical rot.
	Loblolly pine (Pinus taeda) [hard]	
235	Coleosporium apocynaceum, C. lacinariae, C. minutum	Needle rust.
	Cronartium comandrae	Comandra blister rust.
	Hypoderma lethale	Needle spot.
	Lophodermium pinastri	Needle spot.
	Lodgepole pine (Pinus contorta) [hard]	
236	Atropellis pinicola, A. piniphila	Atropellis canker.
237	Coleosporium solidaginis	Needle rust.
238	Cronartium comandrae	Comandra blister rust.
239	C. comptoniae	Sweet fern blister rust.
240	C. filamentosum	Paintbrush blister rust.
241	C. harknessii	Western gall rust.
242	Elytroderma deformans	Needle cast.
243	Fomes pini	Red ring rot.
244	Hypodermella concolor, H. medusa, H. montivaga, H. montana	Needle cast.
245	Peridermium weirii	Needle rust.
	Longleaf pine (Pinus palustris) [hard]	
246	Coleosporium apocynaceum C. inconspicuum, C. lacinariae	Needle rust.
247	Cronartium strobilinum	Pine cone rust.
	Fomes pini	Red ring rot.
	Peridermium gutamalense	Needle rust.
248	Polyporus schweinitzii	Root and butt rot.
	Red pine (Pinus resinosa) [hard]	
249	Armillaria mellea	Shoestring root rot.
250	Atropellis tingens	Atropellis canker.
251	Chilonectria cucurbitula	Burn blight.
252	Coleosporium campanulae, C. solidaginis	Needle rust.
253	Dothistroma pini	Needle spot.
	Fomes annosus	Butt rot.
	Peliullaria pulluians	Needle blight.
	Polyporus schweinitzii	Root and butt rot.
254	Pythium irregulare	Damping off.
255	Rhizina inflata	Rhizina root rot.
256	Rhizoctonia solania	Damping off.
	Scotch pine (Pinus sylvestris) [hard]	
257	Cronartium comandrae	Comandra blister rust.
258	Cronartium harknessii	Western gall rust.
259	Sphaeropsis ellisii	Burn bright.
	Shortleaf pine (Pinus echinata) [hard]	
260	Caliciopsis pinea	Caliciopsis canker.
261	Coleosporium helianthi, C. inconspicuum	Needle rust.
262	Cronartium cerebrum	Globose gall rust.
	Slash pine (Pinus elliottii) [hard]	
263	Atropellis tingens	Atropellis canker.
264	Coleosporium apocynaceum	Needle rust.
265	Cronartium fusiforme	Fusiform gall rust.
266	C. strobilinum	Pine cone rust.
267	Fomes annosus	Root rot.
	F. pini	Red ring rot.
	Hypoderma lethale	Needle spot.
	Lophodermium pinastri	Needle spot.
268	Polyporus schweinitzii	Root and butt rot.
	Virginia pine (Pinus virginiana) [hard]	
269	Atropellis piniphila	Atropellis canker.
270	Coleosporium inconspicuum	Needle rust.
271	Fomes annosus	Root rot.
272	F. pini	Red heart rot.
273	Peridermium appalacianum	Virginia pine rust.
	Western yellow pine (Pinus ponderosa) [hard]	
274	Atropellis arizonica, A. piniphila	Atropellis canker.
275	Coleosporium solidaginis	Needle rust.
276	Cronartium comandrae	Comandra blister rust.
277	C. comptoniae	Sweet fern blister rust.
278	C. filamentosum	Paintbrush blister rust.
279	C. quercuum	Gall rust.

	Host Plant and Pathogen	Disease
	Western yellow pine (Pinus ponderosa) [hard] (concluded)	
291	Cronartium harknessii	Western gall rust.
292	Dasyscypha ellisiana	Dasyscypha canker.
293	Elytroderma deformans	Witches'-broom and needle cast.
294	Fomes laricis	Brown cubical rot.
295	F. pini	Red ring rot.
296	Hypodermella medusa	Needle cast.
297	Lentinus lepideus	Brown cubical rot.
	Eastern white pine (Pinus strobus), Sugar pine (P. lambertiana), Western pine (P. monticola) [soft]	
298	Armillaria mellea	Shoestring root rot.
299	Atropellis pinicola	Atropellis canker.
300	Bifusella linearis	Needle cast.
301	Caliciopsis pinae	Caliciopsis canker.
302	Cronartium ribicola	White pine blister rust.
303	Fomes annosus	Root and butt rot.
304	F. laricis	Brown cubical rot.
305	F. pini	Red ring rot.
306	Hypoderma desmazierii	Needle cast.
307	Lentinus lepideus	Brown cubical rot.
308	Lophodermium pinastri	Needle cast.
309	Neopeckia coulteris	Brown felt blight.
310	Polyporus circinatus	Red root and butt rot.
311	Phacidium planum	Needle blight.
312	Sparassis radicata	Sparassis root rot.
	Poplar (Populus spp)	
313	Armillaria mellea	Shoestring root rot.
314	Ciborinia whetzelii	Ink spot.
315	Cytospora chrysosperma	Cytospora canker.
316	Dothichiza populea	Dothichiza canker.
317	Fomes applanatus	White butt rot.
318	F. fomentarius	White mottled rot.
319	F. igniarius	White heart rot.
320	Fusicladium radiosum	Shoot blight.
321	Hypoxylon pruinatum	Hypoxylon canker.
322	Limospora tetraspora	Leaf blight.
323	Melampspora bigelowii, M. medusae, M. occidentalis	Leaf spot.
324	Marssonia populi	Leaf spot and shoot blight.
325	Nectria galligena	Nectria canker.
326	Neofabraea populi	Neofabraea canker.
327	Sclerotinia bifrons	Ink spot.
328	Septoria musiva	Septoria canker.
329	S. populicola	Leaf spot.
330	Taphrina aurea	Yellow leaf blister.
331	T. johansonii	Catkin blister.
332	Trametes suaveolens	Soft white rot.
333	Uncinula salicis	Powdery mildew.
334	Valsa nivea, V. sordida	Valsa canker.
335	Xylaria digitata	Xylaria root rot.
	Port-Orford-cedar (Chamaecyparis lawsoniana)	
336	Phytophthora lateralis	Chamaecyparis root rot.
	Red cedar, western (Thuja plicata)	
337	Coryneum thujinum	Leaf blight.
338	Fomes sigrolimitatus	White pocket rot.
339	Keithia thujina	Cedar leaf blight.
340	Poria albipelleucida	White ring rot.
341	P. asiatica	Brown cubical rot.
342	P. vierii	Laminated root rot.
	Redwood (Sequoia sempervirens)	
343	Poria albipelleucida	White ring rot.
344	P. sequoia	Brown pocket rot.
	Spruce, black (Picea mariana)	
345	Chrysomyxa cassandrae, C. chiogenis, C. ledi, C. ledicola	Needle rust.
346	C. pyrolae	Spruce cone rust.
347	Lophodermium filiforme, L. picea	Needle cast.
348	Peridermium coloradense	Witches'-broom.
349	Phacidium expansum	Needle blight.
	Spruce, blue (Picea pungens)	
350	Chrysomyxa cassandrae, C. ledi, C. ledicola	Needle rust.
351	C. pyrolae	Spruce cone rust.
352	Peridermium coloradense	Witches'-broom.

	Host Plant and Pathogen	Disease
	Spruce, Engelmann (Picea engelmannii)	
353	Chrysomyxa ledicola	Needle rust.
354	C. pyrolae	Spruce cone rust.
355	C. weirii	Needle rust.
356	Echinodontium tinctorium	Brown stringy rot.
357	Peridermium coloradense	Witches'-broom.
358	Sparassis radicata	Sparassis root rot.
	Spruce, Norway (Picea abies)	
359	Ascochyta piniperda	Needle spot.
360	Chrysomyxa cassandrae, C. ledi	Needle rust.
361	C. pyrolae	Spruce cone rust.
362	Hymenochaete agglutinans	Smotheriog disease.
363	Peridermium coloradense	Witches'-broom.
364	Phoma piciena	Needle blight.
	Spruce, red (Picea rubra)	
365	Ascochyta piniperda	Needle spot.
366	Chrysomyxa cassandrae, C. empetri, C. ledi, C. ledicola	Needle rust.
367	C. pyrolae	Spruce cone rust.
368	C. weirii	Needle rust.
369	Corticium galactinum	Corticium rot.
370	Lophodermium filiforme, L. picea	Needle cast.
371	Phoma piceina	Needle blight.
372	Polyporus borealis	White mottled rot.
	Spruce, Sitka (Picea sitchensis)	
373	Chrysomyxa empetri	Spruce rust.
374	C. ledicola, C. piperiana	Needle rust.
375	Fomes laricis	Brown cubical rot.
376	F. pini	Red ring rot.
377	F. pinicola	Brown cubical rot.
378	Lenticus kauffmanii	Brown pocket rot.
379	Peridermium coloradense	Witches'-broom.
380	Poria monticola	Brown cubical rot.
	Spruce, white (Picea glauca)	
381	Chrysomyxa cassandrae, C. chiogenis, C. empetri, C. ledi, C. ledicola	Needle rust.
382	C. pyrolae	Spruce cone rust.
383	Peridermium coloradense	Witches'-broom.
384	Pucciniastrum americanum, P. arctium	Needle rust.
385	Rhizina inflata	Rhizina root rot.
	Sycamore (Platanus spp)	
386	Endoconidiophora sp	Loodon plane canker stain.
387	Gnomonia veneta	Anthracnose.
	Sweetgum (Liquidambar styraciflua)	
388	Polyporus ludovicianus	White pocket rot.
389	P. fissilis	Butt rot.
	Walnut (Juglans nigra)	
390	Armillaria mellea	Shoestring root rot.
391	Fomes everhartii	White heart rot.
392	Phymatotrichum omnivorum	Phymatotrichum root rot.
393	Phytophthora cinnamomi	Root rot.
	White-cedar, Atlantic (Chamaecyparis thyoides)	
394	Gymnosporsangium bisseptatum	Spindle-shaped gall rust.
395	G. ellisii	Witches'-broom rust.
396	G. hyalinum	Frisiforme gall rust.
397	G. transformans	Chokeberry-southern white cedar rust.
	White-cedar, northern (Thuja occidentalis)	
398	Coniphora puteana	Brown cubical rot.
399	Keithia thujina	Cedar leaf blight.
	Willow (Salix spp)	
400	Botryosphaeria ribis	Botryosphaeria canker.
401	Cytospora pulcherrima	Cytospora canker.
402	Fomes igniarius	Heart rot.
403	Fusicladium salicicerdum	Willow scab.
404	Melamspora abieti-capraearum	Leaf rust.
405	Physalospora miyabeana	Black canker.
406	Polyporus squamosus	White rot.
407	Trametes suaveolens	Soft white rot.
408	Uncinula salicis	Powdery mildew.
409	Valsa nivea, V. sordida	Valsa canker.
	Yellow-poplar (Liriodendron tulipifera)	
410	Nectria magnoliae	Nectris canker.

Part I: PARASITES OF MAN

	Parasite	Geographic Distribution	Infective Stage	Portal of Entry	Location in Man: Definite Stages — Immature Stage	Location in Man: Definite Stages — Primary Site	Location in Man: Definite Stages — Secondary Site	Reservoir Host of Definitive Stage	Other Obligate Host or Vector	Identification — Stage	Identification — Source
	Protozoa										
1	Entamoeba coli	World-wide; most common in warm climates.	4-nucleate cyst.	Mouth[1].	None described.	Lumen, large intestine.	None.	Monkey(?).	None.	Trophozoite, cyst.	Feces.
2	E. histolytica					Wall, large intestine.	Other viscera, skin.	Monkey, dog, rat(?).			Feces, visceral or skin abscesses.
3	Balantidium coli						None.	Swine, monkey(?).			
4	Giardia lamblia					Duodenal crypts.	Gallbladder(?).	Rat(?).	Sheep(?).		Feces.
5	Leishmania brasiliensis	W. Hemisphere from S. Mexico to N. Argentina.	Leptomonad.	Skin[2].		Skin.	Mucous membranes.	Dog, possibly other mammals.	Sandfly (Phlebotomus).	Leishmanial. Leptomonad.	Reticulo-endothelial cells, skin, viscera. Culture.
6	L. donovani	China, India, Africa, Mediterranean area, S. America.					Reticulo-endothelium (fundamental).	Dog, rodents.			
7	L. tropica	W. India, Middle East, Near East, N. Africa.					Mucous membranes, (rare).				
8	Trichomonas vaginalis	Relatively common, both sexes.	Trophozoite (only stage known).	Vulva[1] or urethra.		Vaginal folds.	Bladder.	None.	None.	Trophozoite.	Urine, vaginal smear.
9	Trypanosoma cruzi	Western Hemisphere, from U.S.A. to N. Argentina.	Metacyclic trypanosome.	Skin[1], conjunctiva.		Skin.	In tissues, blood.	Many mammals.	Triatomid bugs.	Trypanosomal. Leishmanial. Crithidial.	Blood, tissues. Culture.
10	T. gambiense	W. and Cent. Africa.		Skin[2].			Blood, lymph nodes, CNS.	Cattle(?), Wild game, mammals.	Tsetse fly (Glossina)	Trypanosomal.	Blood, gland juice, spinal fluid.
11	T. rhodesiense	Cent. and E. Africa.									
12	Plasmodium falciparum	Temperate or warm climates.	Sporozoite.	Skin[2].	Schizonts in hepatic parenchyma.	Exo-erythrocytic foci.	Erythrocytes.	None.	Mosquito (Anopheles spp)	Trophozoites, schizonts, gameto-cytes.	Blood.
13	P. malariae										
14	P. vivax										
15	Toxoplasma gondii	World-wide.	Trophozoite.	Unknown.	None known.	Reticulo-endothelium, many parenchymal cells.	Brain, retina.	Many mammals and birds.	None known.	Trophozoite or pseudo-cyst.	Focal areas of necrosis.
	Platyhelminthes										
16	Diphyllobothrium latum	N. temperate zones; Argentinian, Chilean lakes.	Sparganum larva in fish flesh.	Mouth.	Develops in small intestine.	Attached to small intestine.	None known.	Dog, bear, cat.	Diaptomus, Cyclops; fresh-water fish.	Eggs.	Feces.
17	Dipylidium caninum	Warm climates.	Larva in hemocoel of dog flea.				None.	Dog, cat.	Dog, cat, human flea.	Proglottids.	Feces.
18	Echinococcus granulosus	World-wide; common in southern S. America.	Eggs in dog's excreta.		Develops in liver, lungs.		Hydatid cysts in human viscera.	Dog, wild relatives.	Sheep, cattle, swine (alternating with dog).	Hydatid cyst with scolices.	Aspiration. Exploratory operation.
19	Hymenolepis diminuta	Warm and temperate climates.	Larva in hemocoel of insect.		Develops in duodenum, small intestine.		None.	Rat, mouse.	Rodent flea, grain beetles, meal moths, etc.	Eggs, proglottids.	
20	H. nana		Egg.		Develops in duodenal villi.		None known.		None; may develop in grain beetles.	Eggs.	
21	Taenia saginata	World-wide.	Cysticercus larva in beef.		Develops in small intestine.		(Cysticercus larvae in various viscera)	None.	Cattle.	Proglottids, eggs.	Feces[4].
22	T. solium		Cysticercus larva in pork; egg.						Swine.		
23	Clonorchis sinensis	Sino-Japanese and Indo-Chinese areas.	Larva encysted in flesh of fresh-water fish.	Mouth[5].	In transit from duodenum to bile ducts.	Distal bile ducts.	Pancreatic ducts (rare).	Many fish eating mammals.	Snail, fresh-water fish.	Eggs.	
24	Fasciola hepatica	Sheep-raising countries.	Larva encysted on water plants.			Proximal bile ducts.	Abdominal wall(?), lungs, brain.	Herbivores.	Snail, moist vegetation.		
25	Fasciolopsis buski	Oriental countries.	Larva encysted on water plants.		Develops in duodenum, jejunum.	Attached to duodenum, jejunum.	None.	Swine.	Snail, water plants.		

26	Paragonimus westermani	Sino-Jap. areas, S.W. Pacific islands; northern S. America.	Larva encysted in soft tissues of crabs, crayfish.	Mouth[5].	In transit from duodenum to lungs.	Lungs, near bronchioles.	Abdominal viscera, brain.	Cat, dog, swine, other anumals.	Snail, crab and crayfish; sputum of man.		Sputum, feces.
27	Schistosoma hematobium	Africa, Near East, Middle East, southern Portugal.	Cercaria free in fresh water.	Skin[6].	Migrates in blood vessels.	Vesical venous plexus.	Pelvic organs, rectum, lungs, CNS.	Gerbil.	Bulinid snail.	Eggs.	Urine, feces.
28	S. japonicum	China, Japan, Philippines, Formosa, Celebes.				Mesenteric venules.	Liver, lungs, brain.	Many mammals.	Oncomelanid snail.		Feces.
29	S. mansoni	Africa, Arabia, Brazil, Guianas, Venezuela, West Indies.						Monkey (rarely).	Planorbid snail.		
						Nematoda					
30	Ancylostoma braziliense	Limited distribution in warm climates.	Filariform larva.	Skin[1].	Larvae migrate from skin via blood, lungs to epiglottis, GI tract.	Attached to small intestine.	None.	Dog, cat.	None.	Eggs, (larvae).	Feces (cutaneous tunnels.)
31	A. duodenale	Palearctic region[7], western S. America.						None.			
32	Ascaris lumbricoides	World-wide; more common in warm climates.	Fully embryonated egg.	Mouth[1].	Larvae migrate.	Lumen, small intestine.	Various viscera.	Swine(?).		Eggs.	Feces.
33	Dracunculus medinensis	Warm climates Eastern Hemisphere.	3rd stage larva in Cyclops.	Mouth[6].	In viscera.	Gravid ♀ migrates to skin.	None known.	Fur-bearing mammals.	Cyclops.	Gravid ♀.	Ruptured skin blister.
34	Enterobius vermicularis	World-wide; common in children.	Fully embryonated egg.	Mouth[1].	In transit down small intestine.	Attached to cecum, appendix.	Female genital tract, perianal folds.	None.	Eggs, adults.	Anal swab, anus.	
35	Loa loa	Tropical Africa.	Filariform larva.	Skin[2].	Migrates in subcutaneous tissues.		Orbit, conjunctiva of eye.	None.	Mango-fly (Chrysops).	Microfilariae (sheathed).	Diurnal blood.
36	Necator americanus	Warm climates.		Skin[1].	Larvae migrate.	Attached to small intestine.	None.		None.	Eggs.	Feces.
37	Onchocerca volvulus	Tropical Africa, Mexico, Guatemala, E. Venezuela, Dutch Guiana.		Skin[3].	Adults in subcutaneous nodules. Larvae in skin, may invade eye tissues.		None known.		Blackflies (Simulium).	Microfilariae (unsheathed).	Skin biopsy.
38	Strongyloides stercoralis	Warm, moist climates.		Skin[1].	Larvae migrate.	Within intestinal mucosa.	Lungs.	Dog, chimpanzee.	None	Larvae.	Feces, duodenal aspirate.
39	Wuchereria bancrofti	Warm climates.		Skin[2].	Migrate in lymphatics.	Lymphatics of lower trunk, legs.	Lymphatics of upper trunk.	None.	Mosquito (Aedes, Culex).	Microfilariae (sheathed).	Usually nocturnal blood.
40	Trichinella spiralis	World-wide; common in United States.	Larvae encysted in pork muscle.	Mouth[5].	Enter duodenal mucosa.	In duodenal mucosa.	Larvae migrate, encysted in striped muscle.	Swine, bear, walrus.	None.	Larvae.	Compressed or digested, muscle.
41	Trichuris trichiuris	Warm, moist climates.	Fully embryonated egg.	Mouth[1].	In transit down small intestine.	Attached to cecum, appendix.	Colon, rectum.	Swine(?), ape, monkey.		Eggs.	Feces.

/1/ By direct or indirect contact with body excreta containing the parasite. /2/ From proboscis of insect vector at time of skin puncture to obtain blood or tissue juice from host. /3/ From feces of insect vector while feeding on blood or tissue juice of host. /4/ Also in sputum for P. westermani. /5/ From infected food or contaminated water taken into the mouth. /6/ In contact with infested water. /7/ Tropical and subtropical: Africa, Asia, Europe, U.S.A.

Part II: PARASITES OF ANIMALS OTHER THAN MAN

	Parasite	Geographic Distribution	Definitive Host	Intermediate Host	Primary Location in Definitive Host	Disease; Type of Damage
				Protozoa		
1	Anaplasma marginale	N., S., and C. America, Asia, Africa, France.	Cattle.	None. Mechanical transfer by ticks, tabanid flies, instruments.	Erythrocytes.	Anemia, icterus, fever, extreme splenomegaly.
2	Babesia bigemina	N., S., and C. America, Africa, Europe, Asia, Pacific Islands, Australia.	Cattle.	Tick (Boophilus Rhipicephalus).	Erythrocytes.	Texas fever; anemia, hemoglobinuria.
3	Eimeria tenella	World-wide.	Chicken.	None.	Cecal cells.	Hemorrhagic enteritis.
4	E. zurnii	World-wide.	Cattle.	None.	Intestinal cells.	Enteritis, dysentery.
5	Histomonas meleagridis	World-wide.	Domestic fowl, ruffed grouse, quail, partridge.	None. Transmitted in Heterakis gallinae eggs.	Cecum, liver.	Entero-hepatitis, necrosis, ulceration.

428. SELECTED PROTOZOAN AND HELMINTHIC PARASITES: VERTEBRATES (Concluded)

Part II: PARASITES OF ANIMALS OTHER THAN MAN (Concluded)

	Parasite	Geographic Distribution	Definite Host	Intermediate Host	Primary Location in Definite Host	Disease; Type of Damage
				Protozoa (concluded)		
6	Trypanosoma congolense	Africa.	Cattle, other ruminants, dog.	Tsetse fly (Glossina)	Blood.	Anemia.
				Cestoidea		
7	Moniezia expansa	World-wide.	Sheep, goat, cattle, other ruminants.	Grass mite (several spp).	Small intestine.	Intestinal irritation, slight damage.
8	Taenia pisiformis		Dog, fox, wolf, cat.	Hare, rabbit, rat, squirrel.		Slight enteritis, anal pruritus.
				Nematoda		
9	Ascaridia galli[1]	World-wide.	Chicken, guinea fowl, turkey, goose, wild birds.	None.	Small intestine.	Emaciation.
10	Dictyocaulus viviparus[2]		Cattle, deer.		Bronchus, bronchiole.	Catarrhal inflammation, coughing, emaciation.
11	Dirofilaria immitis[3]	Europe, India, China, Japan, Australia, N. and S. America, Pacific Islands.	Dog, cat, fox, wolf.	Mosquito (Aedes, Anopheles, Culex); flea (Ctenocephalides, Pulex).	Heart, pulmonary artery; microfilariae in blood.	Emaciation, dyspnea, cough, edema.
12	Haemonchus contortus[4]	World-wide.	Sheep, goat, cattle, other ruminants.	None.	Abomasum, small intestine.	Anemia, emaciation.
13	Strongylus vulgaris	Warm climates.	Horse, other equines.		Large intestine.	Anemia, edema, digestive disturbance, emaciation; larvae form aneurisms in mesenteric arteries.

[1] Roundworm. [2] Lungworm. [3] Heartworm. [4] Stomachworm.

429. SELECTED PARASITIC NEMATODES: PLANTS

Most of the nematode parasites of plants are found in largest numbers in close association with roots of plants, or in the upper 16 inches of soil formerly occupied by plant roots. In general, plant parasites can be distinguished from saprophagous or predaceous forms, also found in the soil, by the presence of a protrusile spear or stylet used to puncture and feed on plant cells. The soil is not the only habitat, however, for nematodes. Some live in fresh waters of rivers, lakes and ponds. Others live only in the ocean. Many are parasites of animals and of man.

	Nematode	Geographical Distribution[1]	Hosts[2]	Feeding Habits[3]	Symptoms[4]	Control
1	Awl nematode (Dolichodorus heterocephalus)	Florida, Georgia, Michigan.	Celery, corn, tomato, bean, Chinese water-chestnut; many other plants growing in wet locations.	Vagrant ectoparasites of root tips, sides of succulent roots.	Devitalized root tips, small lesions on sides of roots; sometimes extensive root destruction.	Soil fumigation.
2	Bulb and stem nematode (Ditylenchus spp and closely related forms)	Widespread; temperate zones.	Over 300 different plants, including narcissus, hyacinth, iris, onion, clover, alfalfa, oats, phlox, potato.	Vagrant endoparasites of bulbs, stems, leaves, occasionally roots.	Twisting, wrinkling, distortion of stems and flowers; necrosis and destruction of bulb tissues.	Hot-water treatment of bulbs, corms; crop rotation; field sanitation; methyl bromide fumigation of infected onion and clover seed.
3	Burrowing nematode (Radopholus similis)	India, Indonesia, Formosa, Philippines, Hawaii, Brazil, C. America, Jamaica, La., Fla.	About 50 different plants including citrus, canna, coffee, tea, banana, avocado, black pepper, sugarcane, rice.	Vagrant endoparasites of roots.	Root lesions and disintegration.	Hot water treatment of infected citrus nursery stock; pulling of affected trees, then soil fumigation.
4	Chrysanthemum nematode (Aphelenchoides ritsema-bosi)	N. America, Europe.	About 50 different plants including chrysanthemum, delphinium, phlox, verbena, zinnia, strawberry.	Vagrant endoparasites of buds and foliage.	Crinkled, distorted leaves and leaf spots.	Hot water treatment of dormant plants; parathion sprays.
5	Citrus nematode (Tylenchulus semi-penetrans)	Fla., Tex., Calif., most citrus fruit-growing regions.	Most Citrus spp and closely related genera; olive.	Females are sedentary parasites, partly external, of roots.	Extensive necrosis, discoloration of cortex of small roots.	Plant uninfected stock on clean land.
6	Coconut palm nematode (Aphelenchoides cocophilus)	W. Indies, Br. Guiana, Honduras, Panama, Venezuela.	Coconut, date, and oil palms.	Vagrant endoparasites of roots, trunk (near periphery), leaf petioles.	Disintegration of trunk tissues (causing "red ring") and of root cortex.	No established control measures.
7	Dagger nematodes (Xiphinema spp)	World-wide.	Many plants, trees, shrubs, including laurel oak, pecan, rose, clove, strawberry, corn, oats, some grasses.	Vagrant ectoparasites of root tips, sides of succulent roots.	Devitalized root tips, necrosis of small roots, gall-like swellings, clusters of small stubby branches.	Soil fumigation.
8	Golden nematode of potatoes (Heterodera rostochiensis)	Europe, Bolivia, Peru; in N. America on Long Island, N. Y.	Potato, tomato, several other solanaceous plants.	Sedentary parasites, internal in early stages, becoming largely external as adults; attack roots, other underground parts.	Stunting of plant, decrease in size of root system, but often increase in number of small branch rootlets.	Crop rotation; soil fumigation.
9	Grass nematode (Anguina spp)	Europe, N. America.	Several Agrostis species; other grasses and cereals.	Larvae, ectoparasites around growing point; adults, endoparasites of flower primordia.	Abnormal flowers developing into galls.	Crop rotation; planting gall-free seed.
10	Lance nematode (Hoplolaimus coronatus)	N. America, Philippines.	Many plants including corn, sugarcane, cotton, St. Augustine and other lawn grasses.	Vagrant internal or partly external parasites of roots.	Lesions leading to complete destruction and sloughing off of cortex.	Soil fumigation.

11	Meadow or root lesion nematode (Pratylenchus spp)	World-wide.	Many plants, including tobacco, corn, small grains, cotton, alfalfa, strawberry, trees and shrubs.	Vagrant endoparasites of roots and tubers[5].	Small brown root lesions. Causes "brown root-rot" of tobacco.	Crop rotation, tobacco; row fumigation with D-D.
12	Pin nematodes (Pratylenchus spp)	Netherlands, Br. Isles, Hawaii, N. America.	Many plants, including pineapple, oat, wheat, cowpea, alfalfa, cabbage, cucumber, okra, radish, celery, fig trees.	Vagrant ectoparasites of roots and other underground structures.	Stunting of plants from root injury and retarded root growth.	Fumigation somewhat effective.
13	Potato rot nematode (Ditylenchus destructor)	Europe, Idaho, Wisconsin, Prince Edward Isl.	Potato, carrot, sweetpotato; tulip, iris.	Vagrant endoparasites of tubers, and to some extent of roots.	Destruction of tuber tissues, causing sunken areas, followed by rot.	Crop rotation; planting of clean seed; soil fumigation.
14	Rice root nematode (Radopholus oryzae)	Indonesia, Japan, rice-growing areas of S. E. Asia, Louisiana, Texas.	Rice, various grasses, and related monocotyledonous plants.	Vagrant endoparasites of roots.	Root lesions, destruction of cortex; root hairs; in Indonesia associated with "mentek," a rice root-rot.	No established control measures.
15	Ring nematodes (Criconemoides spp)	Widespread.	Many plants; reported as injuring peach trees and peanut vines.	Semi-sedentary ectoparasites of roots, other underground parts.	Small lesions, stunting of plant.	Soil fumigation.
16	Root knot nematodes (Meloidogyne spp)	World-wide; most common in warm climates.	Over 1800 plants; hosts of individual species more restricted.	Sedentary endoparasites of roots, other underground parts.	Swellings, galls, often local necrosis of tissues; increase or reduction of branch rootlets.	Annual crops: rotation and fumigation. Planting of resistant varieties; hot-water treatment of bulbs, corms, tubers.
17	Soybean cyst nematode (Heterodera glycines)	Japan, China, Wilmington area of N. Carolina.	Soybean, adzuki bean, kidney bean. Snapbeans, annual leapedeza vetch.	Sedentary parasites of roots, internal in early stages, external as adults.	General stunting of plants, reduction in size of root system. Causes a disease known as "yellow dwarf" in Japan and China.	Crop rotation; soil fumigation.
18	Spiral nematodes (Rotylenchus and Helicotylenchus spp)	Widespread, in tropical and subtropical regions.	Many kinds of plants: ornamental, grass, bean, cowpea, pineapple.	Vagrant ectoparasites, occasionally endoparasites of roots and other underground parts.	Stunting of plant from retarded root growth; lesions may occur.	Soil fumigation.
19	Spring crimp nematode of strawberries (Aphelenchoides fragariae)	Europe, Br. Isles, Massachusetts, Connecticut, Delaware, Maryland.	Strawberry.	Vagrant ectoparasites of buds between young developing leaves.	Small, crinkled, distorted foliage.	Set new beds with uninfested plants.
20	Sting nematode (Belonolaimus gracilis)	S. Atlantic states.	Bean, beet, cabbage, celery, citrus, corn, cotton, cowpea, grass, millet, okra, onion, peanut, pine seedling, soybean, strawberry.	Vagrant ectoparasites of root tips, sides of succulent roots, other underground parts.	Devitalized root tips, root lesions, causing many short stubby branched roots, severely stunted plants.	Soil fumigation.
21	Stubby root nematodes (Trichodorus spp)	Widespread; important in S. E. U.S.A., S. Calif.	Many plants, including beet, celery, cabbage, cauliflower, chayote, fig.	Vagrant ectoparasites of root tips.	Devitalized root tips causing numerous short, stubby branch rootlets.	No satisfactory control known.
22	Stunt nematodes (Tylenchorhynchus spp)	Apparently widespread.	Many plants including cotton, oats, tobacco, wheat, sugar cane.	Mostly external, occasionally internal vagrant parasites of roots.	Stunting of plant from retarded root growth.	Tobacco: row fumigation with ethylene dibromide.
23	Sugar beet nematode (Heterodera schachtii)	Europe, Australia, Canada, U.S.A.	Over 100 plants, including sugar beet, table beet, mangelwurzel, cabbage, cauliflower, kale, broccoli, turnip, rutabaga, mustard.	Sedentary parasites of roots, other underground parts; internal in early stages, external as adults.	Stunting of plant, overall decrease in size of root system, often increase in number of small branch rootlets.	Crop rotation; soil fumigation with D-D before planting (sugar beet).
24	Summer crimp nematode of strawberries (Aphelenchoides besseyi)	S.E. U. S. A., Maryland-Texas.	Strawberry, rice.	Vagrant ectoparasites of buds and growing points between young developing leaves.	Small, crinkled, distorted foliage.	Set new beds with uninfested plants. Hot-water treatment or methyl bromide fumigation for rice seed.
25	Wheat nematode (Anguina tritici)	S. and E. Asia, Egypt, Australia, Europe, S. Atlantic states.	Wheat, rye, emmer, spelt.	Larvae, ectoparasites around growing point; adults, endoparasites of flower primordia.	Stunted plants, distorted foliage, galls instead of seed.	Plant gall-free seed (galls may be removed by salt brine flotation or mechanical separators).

/1/ Information on the geographical distribution of plant parasitic nematodes is fragmentary and incomplete, even for the best known species. Undoubtedly distribution is far wider than indicated.
/2/ Species of nematodes within a given genus vary in their ability to attack plants; some have a rather wide host range; others are hightly host-specific, attacking only one or two crop plants.
/3/ Although parasitic nematodes feed on all parts of plants, feeding habits and particular tissues attacked vary, depending on the species, host plant and stage of development of the host and parasite. /4/ Symptoms of nematode damage are often difficult to distinguish from those caused by other organisms or by poor growing conditions; hence it is important in making a diagnosis to find the nematode in the diseased tissues or soil adjacent to the roots of affected plants. /5/ All species in the genus Pratylenchus are root parasites except P. mahogani and P. scribneri, observed in diseased mahogany wood and potato tubers, respectively.

Except where otherwise indicated, the common name of the disease is identical with that of the virus.

	Virus	Distribution	Principal Plant Host	Principal Insect Vector	Other Means of Transmission	Symptoms
1	Abacá bunchy-top (Marmor abacá)	Philippine Islands	Abacá (Musa textilis)	Aphid (Pentalonia nigronervosa)		Chlorotic spots; reduction in leaf size.
2	Abutilon-variegation (M. abutilon)	West Indies	Flowering maple (Abutilon striatum)		Grafting, except bark grafting; seeds.	Systemic chlorotic mottling.
3	Alfalfa-mosaic (M. medicaginis)	United States	Alfalfa (Medicago sativa)	Aphid (Macrosiphum pisi, M. solanifolii)	Leaf rubbing.	Systemic chlorotic mottling, often masked.
4	Aster-yellows (Chlorogenus callistephi)	United States, Bermuda	Aster (Callistephus chinensis)	Leafhopper (Macrosteles divisus and others)	Grafting; dodder.	Leaves chlorotic, small; shoots many, erect; flowers virescent.
5	Bean-mosaic (Marmor phaseoli)	Almost world-wide	Bean (Phaseolus vulgaris)	Aphid (including Aphis rumicis)	Leaf abrasion; seeds.	Systemic chlorotic mottling.
6	Bean-mosaic, southern (M. laeziofaciens)	Southern United States	Bean (P. vulgaris)		Leaf rubbing; seeds.	Some varieties mottle; others show localized or systemic necrosis.
7	Beet-yellows (Corium betae)	Belgium, Holland Denmark, England	Beet (Beta vulgaris)	Aphid (including Myzus persicae and Aphis fabae)		Leaves yellow, thick, brittle; necrosis in secondary phloem.
8	Cassava-mosaic (Ruga bemisiae)	Africa, Java	Cassava (Manihot utilissima)	White-fly (Bemisia nigeriensis, B. gossypiperda)		Leaves distorted, mottled; plants stunted; side-branches numerous.
9	Cauliflower-mosaic (Marmor crucifer-arum)	United States, England	Cauliflower (Brassica oleracea)	Aphid (including Brevicoryne brassicae)	Leaf abrasion.	Systemic chlorotic mottling; leaves distorted; plant dwarfed.
10	Clover club-leaf (Aureogenus clavifolium)	United States, (New Jersey)	Clover, crimson (Trifolium incarnatum)	Leafhopper (Agalliopsis novella)		Plant dwarfed; leaves small, yellowed or reddened at margins.
11	Cotton leaf-curl (Rugs gossypii)	The Sudan, Nigeria	Cotton (Gossypium hirsutum)	White-fly (Bemisia gossypiperda)	Grafting.	Leaves pale-spotted, puckered, unsymmetrical; internodes shortened.
12	Cranberry false-blossom (Chlorogenus vaccinii)	Eastern United States, Canada	Cranberry (Vaccinium macrocarpon)	Leafhopper (Ophiola striatula)	Dodder.	Flowers small, erect, streaked; calyx enlarged; fruit small.
13	Cucumber-mosaic (Marmor cucumeris)	Almost world-wide	Cucumber (Cucumis sativus)	Aphid (including Myzus persicae, Aphis gossypii)	Leaf rubbing; dodder.	Leaves mottled, distorted, small; plant stunted; fruits mottled.
14	Cucurbit-mosaic (M. sastrictum)[1]	England	Cucumber (C. sativus)		Leaf rubbing.	Chlorotic mottling and distortion of foliage; plant stunted.
15	Dahlia-mosaic (M. dahliae)	United States, Holland, Germany, England	Dahlia (Dahlia pinnata)	Aphid (M. persicae)	Grafting.	Systemic chlorotic mottling or masked symptoms.
16	Lettuce-mosaic (M. lactucae)	World-wide	Lettuce (Lactuca sativa)	Aphid (M. persicae, Macrosiphum gei)	Leaf abrasion; seeds.	Clearing of veins, followed by systemic chlorotic mottling.
17	Maize-streak (Fractilinea maidis)	Africa	Corn (Zea mays)	Leafhopper (Cicadulina mbila, C. zeae, C. storeyi)		Chlorotic spotting and streaking of leaves.
18	Onion yellow-dwarf (Marmor capae)	United States, Germany, New Zealand, U.S.S.R.	Onion (Allium cepae)	Aphid (including Aphis rumicis, A. maidis)	Leaf rubbing.	Leaves yellowed, crinkled; plants dwarfed; bulbs small; seeds few.
19	Peach phony-disease (Nanus mirabilis)	Southeastern United States	Peach (Prunus persica)	Leafhopper (including Homalodisca triquetra)	Root grafting.	Foliage abnormally green; tree dwarfed; fruit small.
20	Peach-rosette (Carpophthora rosettae)	United States	Peach (P. persica)		Budding; dodder.	Stems short with dwarfed leaves; veins thickened; tree dies soon.
21	Peach X-disease (C. lacerans)	United States	Peach (P. persica)	Leafhopper (including Colladonus spp)	Budding.	Leaves light green, tattered; old leaves drop; fruit bitter.
22	Peach-yellows (Chlorogenus persicae)	Eastern United States, Eastern Canada	Peach (P. persica)	Leafhopper (Macropsis trimaculata)	Budding.	Leaves chlorotic; shoots erect, thin, numerous; tree dies soon.
23	Peanut-rosette (Marmor arachidis)	Africa, Madagascar, Java	Peanut (Arachis hypogaea)	Aphid (Aphis laburni)	Grafting.	Leaves small, chlorotic or mottled; internodes short; seeds few.
24	Potato aucuba-mosaic (M. aucuba)	United States, Europe, British Isles	Potato (Solanum tuberosum)	Probably aphid (Myzus persicae)	Leaf rubbing.	Yellow mottling of foliage; some necrosis in tubers.
25	Potato leafroll (Corium solani)	Wherever potatoes are grown	Potato (S. tuberosum)	Aphid (especially M. persicae)	Grafting.	Leaves thick, leathery, rolled, starchy; plant small; tubers few.
26	Potato mild-mosaic (Marmor solani)	United States, England, Holland	Potato (S. tuberosum)	Aphid (Aphis abbreviata and M. persicae)	Leaf rubbing.	Mild chlorotic mottling or masked symptoms in most varieties.

27	Potato-mottle (Annulus dubius)	World-wide	Potato (Solanum tuberosum)		Leaf rubbing; root and leaf contacts.	No obvious disease, or very mild chlorotic mottling.
28	Potato spindle-tuber (Acrogenus solani)	United States, Canada	Potato (S. tuberosum)	Aphid (Myzus persicae, Macrosiphum solanifolii)	Leaf rubbing; seed-piece cutting.	Leaves small, erect, dark green; plant brittle; tubers tapered.
29	Potato-veinbanding (Marmor upsilon)	United States, Brazil, England, France	Potato (S. tuberosum)	Aphid (especially Myzus persicae)	Leaf rubbing.	Chlorotic mottling, necrotic stem-streak, or no obvious disease.
30	Potato witches'-broom (Chlorogenus solani)	United States, U.S.S.R.	Potato (S. tuberosum)		Tuber-core and stem grafts.	Leaves small, pale; branches numerous, spindly; tubers small.
31	Potato yellow-dwarf (Aureogenus vastans)	United States, Canada	Potato (S. tuberosum)	Leafhopper (Aceratagallia sanguinolenta)	Leaf abrasion in some hosts; grafting.	Leaves yellowed; plant dwarfed; tubers few, small, often cracked.
32	Rice-dwarf (Fractilinea oryzae)	Japan, Philippine Islands	Rice (Oryza sativa)	Leafhopper (including Nephotettix apicalis)		Leaves chlorotic, spotted, streaked; internodes and roots short.
33	Sandal-spike (Chlorogenus santali)	Southern India	Sandal (Santalum album)	Leafhopper (Jassus indicus)	Grafting, except root grafting.	Leaves small; internodes short; flowers eventually suppressed.
34	Strawberry yellow-edge (Marmor marginans)	United States, England, France, New Zealand	Strawberry (Fragaria hybrida)	Aphid (Aphis fragaefolii)	Grafting.	Central leaves dwarfed, yellow-edged, lacking red color.
35	Sugar beet curly-top (Ruga verrucosans)	Western North America	Sugar beet (Beta vulgaris)	Leafhopper (Eutettix tenellus)	Grafting; dodder.	Leaves curled; enations on veins; plant stunted; rootlets many.
36	Sugar cane chlorotic streak (Fractilinea quarta)	United States, Java, Queensland, Hawaii, Puerto Rico	Sugar cane (Saccharum officinarum)	Leafhopper (Draeculacephala portola)		Long, narrow, white longitudinal streaks in leaves; yield reduced.
37	Sugar cane Fiji-disease (Galla fijiensis)	Australia and islands of the Pacific	Sugar cane (S. officinarum)	Leafhopper (Perkinsiella saccharicida, P. vastatrix)	Sugar cane Fiji-disease.	Leaves short, crumpled, darkened; galls on veins; roots dwarfed.
38	Sugar cane mosaic (Marmor sacchari)	Nearly everywhere sugar cane is grown	Sugar cane (S. officinarum)	Aphid (including Aphis maidis)	Needle puncture.	Systemic chlorotic mottling; vacuolate intracellular bodies.
39	Tobacco-etch (M. srodens)	United States	Tobacco (Nicotiana tabacum)	Aphid (especially Myzus persicae)	Leaf rubbing.	Systemic chlorotic mottling with traces of whitish etching.
40	Tobacco leaf-curl (Ruga tabaci)	Africa, India, Sumatra, Formosa	Tobacco (N. tabacum)	White-fly (Bemisia gossypiperda)	Grafting.	Leaves curled, wrinkled; veins thick; enations; plant stunted.
41	Tobacco-mosaic (Marmor tabaci)	World-wide	Tobacco (N. tabacum)		Leaf rubbing; dodder; soil.	Systemic chlorotic mottling; some distortion of leaves.
42	Tobacco-necrosis (M. lethale)	England, Scotland, Australia	Tobacco (N. tabacum)		Leaf rubbing; soil.	Necrosis in mid-rib and veins of lower leaves in winter.
43	Tobacco-ringspot (Annulus tabaci)	United States	Tobacco (N. tabacum)		Leaf rubbing; seeds of petunia.	Necrotic ringlike primary and secondary lesions; later recovery.
44	Tomato bushy-stunt (Marmor dodecahedron)	British Isles	Tomato (Lycopersicon esculentum)		Leaf rubbing; dodder.	Foliage yellowed, plant stunted; axillary buds stimulated.
45	Tomato spotted-wilt (Lethum australiense)	Almost world-wide	Tomato (L. esculentum)	Thrips tabaci, Frankliniella moultoni, F. schultzei	Leaf abrasion.	Bronze-ring lesions; necrosis or mottling; fruit discolored.
46	Turnip-mosaic (Marmor brassicae)	United States, New Zealand, England	Turnip (Brassica rapa)	Aphid (Brevicoryne brassicae, Myzus persicae)	Leaf rubbing.	Leaves mottled and distorted; plant stunted.
47	Wheat-mosaic (M. tritici)	United States, Japan	Wheat (Triticum aestivum)		Leaf abrasion.	Systemic chlorotic mottling; dwarfing; vacuolate inclusions.
48	Wheat streak-mosaic (M. virgatum)	United States, Canada	Wheat (T. aestivum)	Mite (Aceria tulipae)	Leaf abrasion.	Systemic chlorotic mottling and streaking of leaves.
49	Winter-wheat mosaic (Fractilinea tritici)[2]	U.S.S.R.	Wheat (T. aestivum)	Leafhopper (Deltocephalus striatus)		Chlorotic mottling; phloem necrosis; vacuolate inclusions.
50	Wound-tumor (Aureogenus magnivena)	United States	Clover, crimson (Trifolium incarnatum)	Leafhopper (Agalliopsis novalla, Agallia constricta)		Experimentally, veins thickened; enations; plant dwarfed.

/1/ Agent of "English cucumber-mosaic" disease. /2/ Agent of "Russian winter-wheat mosaic" disease.

Part I: SUPERFICIAL MYCOSES

	Fungus	Diseases Produced	Natural Occurrence	Microscopic Appearance in Skin	Microscopic Appearance in Nail	Microscopic Appearance in Hair	Microscopic Appearance of Culture on Sabouraud's Agar
1	Cladosporium wernecki	Tinea nigra palmaris		Pigmented, light brown to dark green, branching, septate hyphae which may develop closely septate, swollen cells and chlamydospores.	None.	None.	Pigmented hyphae which produce blastospores laterally and 1 to 3 septate conidia in clusters or in short chains from apicull or short conidiophores.
2	Epidermophyton flocosaum	Tinea pedis T. cruris T. unguium		Abundant, branching, septate hyphae which segment into chains of arthrospores.	Branching, septate hyphae which segment into chains of arthrospores.	None.	Macroconidia abundant, clavate, 2 to 6 cells, blunt-tip, smooth thin walls; occur in clusters of 2 or 3. No microconidia. Abundant chlamydospores.
3	Malassezia furfur	Tinea versicolor		Clusters of spherical, thick-walled, budding cells (3 to 8 μ) and short irregular hyphae.	None.	None.	No culture method available.
4	Microsporum audouini	Tinea capitis T. corporis	Dog (rare) Monkey (rare)	Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix. Sheath of small spores (2-3μ).	Mycelium with chlamydospores. Microconidia infrequent, clavate, 2. 5 to 4 x 3 to 6 μ. Macroconidia rare, rudimentary, and ill-formed.
5	Microsporum canis	Tinea capitis T. corporis T. barbae T. unguium	Cat[1] Dog[1] Horse Monkey		Rare.		Macroconidia numerous, 8 to 15 cells, spindle-shape, thick rough walls, 8 to 15 x 40 to 150 μ. Microconidia few, clavate, 2 to 4 x 3 to 6 μ.
6	Microsporum gypseum	Tinea capitis T. corporis	Cat Mouse Dog[1] Rat Horse[1] Soil[1] Monkey		None.	May be as above; more commonly large-spored ectothrix (5-8μ).	Macroconidia numerous, elliptoid, thin, rough walls, 4 to 6 cells, 8 to 12 x 30 to 50 μ. Microconidia few, clavate.
7	Nocardia minutissima	Erythrasma		Delicate, branching filaments (1 μ or less in diameter), readily fragment into coccoid and bacillary forms.	None.	None.	No culture method available.
8	Piedraia hortai	Black piedra		None.	None.	Nodule on hair shaft consists of brown, dichotomously branched, closely septate hyphae (4 to 8 μ in diameter) and asci containing 2 to 8 ascospores.	Dark, thick-walled, closely septate hyphae; chlamydospores, asci and ascospores are rare.
9	Trichophyton concentricum	Tinea imbricata		Abundant branching, septate hyphae which may segment into chains of arthrospores.	None.	None.	Septate, branching irregular mycelium with chlamydospores, pectinate hyphae, and favic chandeliers.
10	Trichophyton ferrugineum	Tinea capitis T. corporis		Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix. Sheath of small arthrospores (2-3μ).	Irregular mycelium with hyphal swellings and many chlamydospores.
11	Trichophyton gallinae	Favus of poultry[1] and wild birds Tinea capitis T. corporis	Primarily a disease of poultry	Branching, septate hyphae. (Rare in man.)	None.	None.	Macroconidia usually numerous, clavate, 2 to 10 cells, smooth, slightly thickened walls. Microconidia few, small, pyriform to elongate.
12	Trichophyton megnini	Tinea barbae T. capitis T. unguium	Cattle Dog(?)	Branching, septate hyphae.	Branching, septate hyphae which may segment into chains of arthrospores.	Endothrix. Chains of large spherical arthrospores (6 to 8 μ).	Microconidia numerous, small, pyriform to elongate. Macroconidia rare, slightly clavate, 2 to 8 cells.
13	Trichophyton mentagrophytes	Tinea pedis T. cruris T. corporis T. capitis T. unguium T. barbae	Cat Monkey Cattle Mouse[1] Chinchilla Muskrat Dog[1] Rabbit Guinea pig[1] Rat[1] Horse[1]	Branching, septate hyphae which may segment into chains of arthrospores.	Branching, septate hyphae which segment into chains of arthrospores.	Ectothrix. Chains of small arthrospores (3-5μ).	Microconidia numerous, subspherical to pyriform, in terminal clusters or singly along the hyphae. Macroconidia clavate thick walls, 2 to 5 cells, 4 to 6 x 10 to 50 μ.

14	Trichophyton rubrum	Tinea pedis T. unguium T. cruris T. corporis T. barbae T. capitis	Cow (rare) Dog (rare)	Branching, septate hyphae which may segment into chains of arthrospores.		Ectothrix. Chains of large arthrospores (about 5μ).	Microconidia numerous singly along the hyphae and in clusters. Macroconidia infrequent, pencil-shaped thin walls, 4 to 6 x 10 to 50μ.
15	Trichophyton schoenleini	Favus Tinea capitis T. corporis T. unguium	Dog (rare)	Abundant hyphae which may segment into chains of arthrospores throughout cellular debris of scutulum.	Branching, septate hyphae which segment into chains of arthrospores.	Endothrix, Mycelium, occasional arthrospore and numerous air bubbles inside hair.	Irregular mycelium, chlamydospores, hyphal swellings, pectinate hyphae, and favic chandeliers.
16	Trichophyton tonsurans	Tinea capitis T. corporis T. unguium				Endothrix, Large spores in chains (4-7.5μ).	Microconidia numerous, clavate along sides of hyphae or on short conidiophores. Spore-bearing hyphae stains poorly with LPCB. Numerous chlamydospores.
17	Trichophyton verrucosum	Tinea corporis T. capitis T. barbae	Cattle[1]; rare in dog, donkey, dromedary, goat, horse, sheep	Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix, Chains of large arthrospores (5-10μ).	Irregular mycelium. Abundant chlamydospores. Microconidia and macroconidia present on thiamine-enriched media. Best growth at 370C.
18	Trichophyton violaceum	Tinea capitis T. corporis T. barbae T. unguium			Branching, septate hyphae with segment into chains of arthrospores.	Endothrix. Chains of large arthrospores (4-7.5μ).	Irregular mycelium. Abundant chlamydospores and hyphal swellings. Microconidia rare.
19	Trichosporon beigelii	White piedra		Not affected.	None.	Nodule on hair shaft consists of hyphae which segment into spherical to rectangular cells (2 to 8 μ). Budding cells present.	Hyphae segment into rectangular to spherical arthrospores. Budding cells present.

/1/ Host or site of most common occurrence.

Part II: DEEP MYCOSES

	Fungus	Disease	Geographical Distribution	Occurrence in Nature: Animal Host	Occurrence in Nature: Saprophytic Occurrence	Organs and Tissues Frequently Attacked	Susceptible Laboratory Animals	Microscopic Appearance in: Tissue	Microscopic Appearance in: Culture at 25°C	Microscopic Appearance in: Culture at 37°C
1	Actinomyces bovis (A. israeli)	Actinomycosis (Lumpy jaw)	World-wide	Cattle Deer Dog Horse Swine	Man (often) obligate parasite	Cervico-facial region, lung, bone, cecum, appendix, liver	Hamster Mouse	Granules of filamentous, branching, Gram-positive hyphae (1 μ or less in width). Club-shaped accretions on tips of hyphae may be present.	Grows slowly.	Anaerobic, filamentous, branching. Gram-positive hyphae (1 μ or less in width).
2	Allescheria boydii (Monosporium apiospermum) Aspergillus spp (?) Madurella spp Indiella spp Cephalosporium spp Glenospora spp (?) Penicillium spp (?) Sterigmatocystis sp (?) Phialophora jeanselmei	Mycetoma (Madura mycosis; Madura foot)	World-wide; more frequent in tropics	Dog	Soil (A. boydii, P. jeanselmei)	Feet, hands, cutaneous and subcutaneous tissue, bone	Mouse (A. boydii)	Oval, irregular shaped granules (0.5 to 2 mm) made up of segmented branched hyphae (2 to 4 μ in diameter) and chlamydospores.	Allescheria boydii - mycelium with ovoid to pyriform conidia (5 to 7 x 8 to 10 μ) borne singly at ends of long conidiophores. Dark brown, thin-walled perithecia (50 to 200 μ in diameter) containing evanescent asci and elliptical ascospores. Coremia occasionally present.	Similar to cultures at 25°C.
3	Aspergillus spp (A. fumigatus)	Aspergillosis	World-wide	Birds	Grain Soil	Ear, sinus, orbit, vagina, lung, brain	Birds Guinea pig Rabbit	Fragments of septate hyphae and spherical, green conidia.	Conidiophore forms vesicle at tip. Surface covered with sterigmata bearing long chains of conidia.	Similar to growth at 25°C.
4	Blastomyces brasiliensis (Paracoccidioides brasiliensis)	South American blastomycosis (Paracoccidioidal granuloma; Lutz-Splendore-de-Almeida's disease)	South America Central America	Not known	Not known	Mouth, lung, lymph node, gastro-intestinal tract	Guinea pig Hamster Mouse	Multiple budding, thick-walled cells (10 to 60 μ).	Mycelium with rare oval conidia (3 to 5 μ).	Similar to the forms observed in tissue.
5	Blastomyces dermatitidis	North American blastomycosis	U.S.A. Canada Mexico	Dog Horse	Not known	Skin, lung, bone	Guinea pig Mouse	Single budding, thick-walled cells (8 to 15 μ).	Mycelium with oval to pyriform conidia (3 to 5 μ) on conidiophores or attached directly to hyphae.	Similar to the forms observed in tissue.

Part II: DEEP MYCOSES (Concluded)

	Fungus	Disease	Geographical Distribution	Occurrence in Nature: Animal Host	Occurrence in Nature: Saprophytic Occurrence	Organs and Tissues Frequently Attacked	Susceptible Laboratory Animals	Microscopic Appearance in: Tissue	Microscopic Appearance in: Culture at 25°C	Microscopic Appearance in: Culture at 37°C
6	Candida albicans (Monilia albicans)	Candidiasis (Moniliasis; thrush; mycotic vulvo-vaginitis)	World-wide	Poultry	Man (often) Soil (rare)	Mucous membranes, nail, skin, bronchus, lung	Guinea pig Mouse Rabbit Rat	Oval to spherical budding cells (2 to 6 μ) and frequently hyphae which may show clusters of blastospores attached at septations.	Oval to spherical single budding cells (2 to 6 μ). Pseudohyphae and hyphae. Clusters of budding cells often at septations. Thick-walled chlamydospores (6 to 9 μ) on special medium.	Similar to growth at 25°C.
7	Coccidioides immitis	Coccidioidomycosis (Coccidioidal granuloma; valley fever; Posada-Wernicke's disease)	Arid S.W. U.S.A. Northern Mexico Chaco region, S. America	Cattle Dog Gorilla Monkey Rodents Sheep	Soil	Lung, skin, bone, meninges	Guinea pig Hamster Mouse Other rodents	Thick-walled spherules (20 to 60 μ) containing endospores (2 to 5 μ).	Mycelium with arthrospores (2.5 to 3 x 3 to 4 μ).	Similar to growth at 25°C. Under special conditions with special media, tissue spherules obtained in vitro.
8	Cryptococcus neoformans (Torula histolytica)	Cryptococcosis (Torulosis; European blastomycosis; Busse-Buschke's disease)	World-wide	Cat Cattle Dog Horse	Soil Pigeon droppings	Central nervous system, lung, skin, bone	Mouse Rat	Spherical, single budding, thick-walled cells (5 to 20 μ) surrounded by a wide, gelatinous capsule.	Similar to cells seen in tissue.[1] Abortive hyphae may be seen on primary isolation.	Similar to celle seen in tissue.
9	Geotrichum sp	Geotrichosis	World-wide	Rodents	Soil Milk products	Mouth, intestinal tract, bronchus, lung	Not known	Oblong to rectangular cells with somewhat rounded ends (4 to 8 μ).	Mycelium with segments into rectangular arthrospores. Germ tube forms at corners.	Similar to growth at 25°C.
10	Histoplasma capsulatum	Histoplasmosis (Reticulo-endothelial cytomycosis; Darling's disease)	At least 24 countries of the world	Cat Cattle Dog Horse Mouse Rat Skunk	Soil, especially from avian habitats	Lung, liver, spleen, lymph nodes, mucous membranes, adrenal, kidney	Guinea pig Hamster Mouse	Intracellular oval, budding cells (1 to 5 μ).	Delicate mycelium with thin-walled, subspharical to pyriform conidia (2 to 5 μ) and thick-walled, tuberculated conidia 8 to 20 μ).	Budding cells (1 to 5 μ); must be grown on enriched medium.
11	Hormodendrum pedrosoi H. compactum H. dermatitidis Phialophora verrucosa	Chromoblastomycosis (Chromomycosis; verrucose dermatitis)	World-wide; more frequent in tropics	Not known	Soil, wood (H. dermatidis, P. verrucosa)	Usually on lower extremities, cutaneous and subcutaneous tissue, lymphatics	Mouse Rat	Single or clustered, spherical, thick-walled, dark brown cells (6 to 12 μ) which multiply by splitting not budding. [thecа type-conidia on swollen, club-like type-conidia borne structure on a flask-shaped conidiophore.	Three types of sporulation characterize this group of fungi: Hormodendrum type-conidia in branching chains arising terminally from conidiophore, Acroborne acropleurogenously conidiophore, Phialophora borne with a terminal cup-like	Similar to cultures at 25°C.
12	Mucor spp (Rhizopus oryzae, R. arrhisus. Absidia corymbifera	Mucormycosis	Probably world-wide	Birds Cattle Dog Horse Swine	Soil	Lung, brain, eye, intestinal tract	Diabetic rabbit	Nonseptate, coenocytic hyphae (6 to 15 μ in width).	Broad, coenocytic mycelium with brown sporangiophores.	Similar to growth at 25°C.
13	Nocardia asteroides N. brasiliensis N. madurae N. pellitieri N. paraguayensis	Nocardiosis (Actinomycotic mycetoma; Madura foot)	World-wide; more frequent in tropics	Cattle Dog	Soil	Lung, brain, cutaneous and subcutaneous tissue	Guinea pig Mouse	Granules of Gram-positive, branching, delicate hyphae. Occasionally not in granule form. N. asteroides and N. brasiliensis are partially acid-fast.	Delicate, branching hyphae (1 μ or less in width) which may or may not fragment into bacillary forms of varying length.	Similar to growth at 25°C.
14	Rhinosporidium seeberi	Rhinosporidiosis	World-wide; more frequent in India & Ceylon	Cow Horse Mule	Not known	Mucous membranes, nose, eye, vagina, penis, skin	Not known	Thick-walled spherule (50 to 350 μ) with pore, containing up to 16,000 endospores (7 to 9 μ).	No culture method available.	
15	Sporotrichum schenckii	Sporotrichosis	World-wide	Cat Cow Dog Horse Mouse Mule Rat	Mine timbers Plants Soil	Hands, feet, cutaneous and subcutaneous tissue, lymphatics	Hamster Mouse Rat	Rarely seen without special stains. Gram-positive, cigar-shaped or spherical to oval, usually intracellular, budding cells (3 to 5 μ). Asteroid forms rare,	Delicate (2 μ in width) hyphae. Pyriform to spherical conidia (2 to 4 x 2 to 6 μ) borne in clusters on lateral branches or laterally along the hyphae.	Cigar-shaped, spharical or oval budding cells. Must be grown on enriched medium.

/1/ Not true of some strains which may be weakly encapsulated in vitro, giving culture a different gross appearance similar to many of the common yeasts.

432. POPULATION, REGISTERED DEATHS AND DEATH RATES, BY RACE AND SEX: U.S.A., 1906-1954

Population estimated as of July 1 for 1906-39, 1941-49 and 1951-54,and enumerated as of April 1 for 1940 and 1950. Rates are per 1000 population in each specified group.

Year	Population of Continental United States[1]	Number of States	Population[2]	Death-registration States[2] Deaths[3]						Rate			
				Number						White		Non-white	
				Total	White		Non-White		Total				
					Male	Female	Male	Female		Male	Female	Male	Female
1 1954	162,414,000	48	161,195,000	1,481,000[6]	748,390[6]	559,760[6]	95,680[6]	77,170[6]	9.25	10.59	7.76	11.4	8.76
2 1953	159,629,000	48	158,306,000	1,517,541	766,703	569,132	100,397	81,309	9.6	11.0	8.0	12.2	10.1
3 1952	157,022,000	48	155,755,000	1,496,838	753,571	561,451	100,356	81,460	9.6	11.0	8.0	12.5	9.6
4 1951	154,360,000	48	153,384,000	1,482,099	747,049	555,920	98,184	80,946	9.7	11.0	8.0	12.5	9.8
5 1950	151,132,000	48	150,697,361	1,452,454	731,366	544,719	96,383	79,986	9.6	10.9	8.0	12.5	9.9
6 1949	149,188,000	48	148,665,000	1,443,607	726,169	542,679	95,122	79,637	9.7	11.0	8.1	12.5	10.0
7 1948	146,631,000	48	146,093,000	1,444,337	725,818	544,771	95,113	78,435	9.9	11.2	8.3	12.7	10.1
8 1947	144,126,000	48	143,446,000	1,445,370	726,104	548,789	92,130	78,347	10.1	11.4	8.5	12.5	10.3
9 1946	141,389,000	48	140,054,000	1,395,617	697,323	535,014	88,366	74,914	10.0	11.2	8.5	12.2	10.0
10 1945	139,928,000	48	138,397,000	1,401,719	697,968	536,191	90,365	77,465	10.6	12.5	8.9	13.5	10.5
11 1944	138,397,000	48	132,885,000	1,411,338	697,731	541,098	92,130	80,379	10.6	12.2	8.8	13.8	11.1
12 1943	136,739,000	48	134,245,000	1,459,544	721,777	559,110	95,708	82,949	10.9	12.2	9.2	14.0	11.6
13 1942	134,860,000	48	133,920,000	1,385,187	685,468	524,476	94,986	80,257	10.3	11.4	8.7	14.0	11.4
14 1941	133,402,000	48	133,121,000	1,397,642	685,672	527,839	99,361	84,770	10.5	11.4	8.9	14.8	12.2
15 1940	131,820,000	48	131,669,000	1,417,269	690,901	540,322	100,102	85,944	10.8	11.6	9.2	15.1	12.6
16 1939	130,879,718	48	130,879,718	1,387,897	672,047	530,931	96,830	83,989	10.6	11.3	9.2	14.7	12.4
17 1938	129,824,939	48	129,824,939	1,381,391	665,559	529,872	99,343	86,617	10.6	11.3	9.2	15.2	12.9
18 1937	128,824,829	48	128,824,829	1,450,427	702,630	552,157	106,204	89,436	11.3	12.0	9.6	16.4	13.4
19 1936	128,053,180	48	128,053,180	1,479,228	712,126	566,253	109,313	91,536	11.6	12.3	9.9	16.9	13.9
20 1935	127,250,232	48	127,250,232	1,392,752	671,298	536,061	100,022	85,371	10.9	11.6	9.5	15.6	13.0
21 1934	126,373,773	48	126,373,773	1,396,903	670,478	540,111	102,119	87,587	11.1	11.7	9.6	15.8	13.5
22 1933	125,578,763	48	125,578,763	1,342,106	641,725	520,673	95,587	84,121	10.7	11.2	9.3	15.1	13.1
23 1932	124,840,471	47	118,903,899	1,293,269	614,093	508,377	90,413	80,386	10.9	11.3	9.6	15.4	13.5
24 1931	124,039,648	47	118,148,987	1,307,253	621,120	509,257	96,510	85,386	11.1	11.5	9.6	16.5	14.5
25 1930	123,076,741	47	117,238,278	1,327,240	625,792	511,092	100,888	89,468	11.3	11.7	9.8	17.4	15.3
26 1929	121,769,939	46	115,317,450	1,369,757	642,463	533,027	103,028	91,239	11.9	12.2	10.4	18.0	15.8
27 1928	120,501,115	45	113,836,160	1,361,197	637,063	531,206	101,828	91,090	12.0	12.3	10.4	18.0	16.2
28 1927	119,038,062	42	107,084,532	1,211,627	572,061	478,297	84,636	76,633	11.3	11.6	10.0	17.2	15.6
29 1926	117,399,225	41	103,822,683	1,257,256	590,852	502,998	86,180	77,226	12.1	12.3	10.8	18.7	16.9
30 1925	115,831,963	40	102,031,559	1,191,971	561,432	474,144	82,041	74,268	11.7	11.8	10.4	18.2	16.6
31 1924	114,113,463	39	99,318,098	1,151,076	539,303	458,314	80,571	72,888	11.6	11.8	10.3	17.9	16.3
32 1923	111,949,945	38	96,788,197	1,174,065	549,623	478,478	75,636	70,328	12.1	12.3	11.0	17.0	16.0
33 1922	110,054,778	37	94,702,901	1,083,952	507,567	443,185	68,360	64,160	11.7	11.9	10.7	15.7	14.8
34 1921	108,541,489	34	87,814,447	1,009,673	475,172	420,421	58,095	55,985	11.5	11.6	10.6	15.7	15.4
35 1920	106,466,420	34	86,079,263	1,118,070	521,440	469,419	64,696	62,515	13.0	13.0	12.1	17.8	17.5
36 1919	105,062,747	33	83,157,982	1,072,246	492,960	442,668	64,217	62,610	12.9	13.0	11.8	18.1	17.8
37 1918	104,549,886	30	79,008,612	1,430,079	706,613	575,920	77,694	69,852	18.1	19.3	15.8	26.7	24.4
38 1917	103,413,743	27	70,234,775	981,239	486,208	396,527	52,315	46,189	14.0	14.6	12.4	21.4	19.4
39 1916	101,965,984	26	66,971,177	924,971	461,432	371,165	43,455	38,919	13.8	14.4	12.4	19.9	18.6
40 1915	100,549,013	24	61,894,847	815,500	415,476	346,813	28,452	24,759	13.2	13.7	12.0	20.8	19.5
41 1914	99,117,567	24	61,963,309	810,314	415,451	343,107	28,129	24,185	13.1	13.7	12.1	20.5	19.4
42 1913	97,226,814	23	58,156,740	802,909	413,225	339,040	27,122	23,522	13.8	14.5	12.5	21.0	19.6
43 1912	95,331,300	22	54,847,700	745,771	388,302	321,229	19,791	16,449	13.6	14.3	12.4	21.3	19.7
44 1911	93,867,814	22	53,929,644	749,918	388,238	325,006	19,895	16,779	13.9	14.5	12.8	21.9	20.6
45 1910	92,406,536	20	47,470,437	696,866	365,042	304,433	15,031	12,350	14.7	15.4	13.6	22.3	21.0
46 1909	90,491,525	18	44,223,513	630,057	327,153	276,398	14,398	12,108	14.2	14.9	13.2	22.3	21.2
47 1908	88,708,976	16	39,634,759	567,245	294,173	246,627	13,186	11,259	14.3	14.7	13.3	22.8	22.0
48 1907	87,000,271	15	34,552,837	550,245	286,269	238,990	13,530	11,456	15.9	16.8	14.5	25.0	23.5
49 1906	85,436,556	15	33,782,288	531,005	274,579	231,974	13,112	11,340	15.7	16.5	14.4	24.7	23.6

/1/ Estimates of armed forces overseas are included in the years 1917-19, 1941-45, 1951-54. /2/ Effective 1933, all of continental United States included. /3/ Exclusive of fetal deaths. For 1940-54, estimates exclusive of deaths among armed forces overseas; rates based on population excluding armed forces overseas. /4/ District of Columbia not included in "Number of States," though represented in all data shown for each year. /5/ Excludes armed forces overseas. /6/ Tentative.

433. AVERAGE REMAINING LIFETIME IN YEARS AT SPECIFIED AGES, BY RACE AND SEX: U.S.A., 1900-1953

For 1900-1902 and 1909-1911, data for the death-registration states of 1900, which consisted of 10 states and the District of Columbia; for 1919-1921, for the death-registration states of 1920, which consisted of 34 states and the District of Columbia; for 1929-1931, 1939-1941, 1949-1951, 1952 and 1953, for the entire continental United States.

Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902	Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902
	White Male								White Female								
1 0	66.8	66.6	66.3	62.8	59.1	56.3	50.2	48.2	21 0	72.9	72.7	72.0	67.3	62.7	58.5	53.6	51.1
2 1	67.7	67.6	67.4	65.0	62.2	60.2	56.3	54.6	22 1	73.6	73.3	72.8	68.9	64.9	61.5	58.7	56.3
3 5	64.0	64.0	63.8	61.7	59.4	58.3	55.4	54.4	23 5	69.8	69.6	69.1	65.6	62.2	59.4	57.7	56.0
4 10	59.2	59.2	59.0	57.0	55.0	54.2	51.3	50.6	24 10	65.0	64.8	64.3	60.9	57.7	55.2	53.6	52.2
5 15	54.4	54.4	54.2	52.2	50.4	49.7	46.9	46.3	25 15	60.1	59.9	59.4	56.1	53.0	50.7	49.1	47.8
6 20	49.8	49.7	49.5	47.8	46.0	45.6	42.7	42.2	26 20	55.3	55.1	54.6	51.4	48.5	46.5	44.9	43.8
7 25	45.2	45.2	44.9	43.3	41.8	41.6	38.8	38.5	27 25	50.5	50.3	49.8	46.8	44.3	42.6	40.9	40.1
8 30	40.6	40.5	40.3	38.8	37.5	37.7	34.9	34.9	28 30	45.7	45.5	45.0	42.2	40.0	38.7	37.0	36.4
9 35	35.9	35.9	35.7	34.4	33.3	33.7	31.1	31.3	29 35	40.9	40.8	40.3	37.7	35.7	34.9	33.1	32.8
10 40	31.4	31.4	31.2	30.0	29.2	29.9	27.4	27.7	30 40	36.2	36.1	35.6	33.3	31.5	30.9	29.3	29.2
11 45	27.0	27.1	26.9	25.9	25.3	26.0	23.9	24.2	31 45	31.7	31.6	31.1	28.9	27.4	27.0	25.5	25.5
12 50	23.0	23.0	22.8	22.0	21.5	22.2	20.4	20.8	32 50	27.3	27.2	26.8	24.7	23.4	23.1	21.7	21.9
13 55	19.2	19.3	19.1	18.3	18.0	18.6	17.0	17.4	33 55	23.0	23.0	22.6	20.7	19.6	19.4	18.2	18.4
14 60	15.8	15.9	15.8	15.1	14.7	15.3	14.0	14.4	34 60	19.0	19.0	18.6	17.0	16.1	15.9	14.9	15.3
15 65	12.9	13.0	12.8	12.1	11.8	12.2	11.3	11.5	35 65	15.3	15.3	15.0	13.6	12.8	12.8	12.0	12.2
16 70	10.3	10.3	10.1	9.4	9.2	9.5	8.8	9.0	36 70	12.0	12.0	11.7	10.5	10.0	9.9	9.4	9.6
17 75	7.9	8.0	7.8	7.2	7.0	7.3	6.8	6.9	37 75	9.1	9.1	8.9	7.9	7.6	7.6	7.2	7.3
18 80	6.1	6.1	5.9	5.4	5.3	5.5	5.1	5.1	38 80	6.7	6.8	6.6	5.9	5.6	5.7	5.4	5.5
19 85	4.7	4.8	4.4	4.0	4.0	4.1	3.9	3.8	39 85	5.1	5.1	4.8	4.3	4.2	4.2	4.1	4.1
20 90	-	-	3.3	3.1	3.0	3.2	3.0	2.9	40 90	-	-	3.5	3.2	3.2	3.2	3.0	3.0

433. AVERAGE REMAINING LIFETIME IN YEARS AT SPECIFIED AGES, BY RACE AND SEX: U.S.A., 1900-1953 (Concluded)

For 1900-1902 and 1909-1911, data for the death-registration states of 1900, which consisted of 10 states and the District of Columbia; for 1919-1921, for the death-registration states of 1920, which consisted of 34 states and the District of Columbia; for 1929-1931, 1939-1941, 1949-1951, 1952 and 1953, for the entire continental United States.

Age		1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902
		Non-white Male[1]							
41	0	59.7	59.1	58.9	52.3	47.6	47.1	34.1	32.5
42	1	61.7	61.4	61.1	55.9	51.1	51.6	42.5	42.5
43	5	58.3	58.0	57.7	52.1	48.7	50.2	44.3	45.0
44	10	53.5	53.3	53.0	48.3	44.3	46.0	40.7	41.9
45	15	48.8	48.5	48.2	43.7	39.8	41.8	36.8	38.3
46	20	44.2	44.0	43.7	39.5	36.0	38.4	33.5	35.1
47	25	39.9	39.7	39.5	35.7	32.7	35.5	30.4	32.2
48	30	35.7	35.6	35.3	32.1	29.5	32.5	27.3	29.3
49	35	31.6	31.4	31.2	28.5	26.4	29.5	24.4	26.2
50	40	27.6	27.5	27.3	25.1	23.4	26.5	21.6	23.1
51	45	23.8	23.8	23.5	21.9	20.6	23.6	18.9	20.1
52	50	20.4	20.4	20.2	19.1	17.9	20.5	16.2	17.3
53	55	17.5	17.5	17.4	16.6	15.5	17.5	13.8	14.7
54	60	14.9	15.0	14.9	14.2	13.2	14.7	11.7	12.6
55	65	12.7	12.8	12.8	12.2	10.9	12.1	9.7	10.4
56	70	11.2	11.1	10.7	10.1	8.8	9.6	8.0	8.3
57	75	9.5	9.3	8.8	8.2	7.0	7.6	6.4	6.6
58	80	8.0	8.0	7.1	6.6	5.4	5.8	5.5	5.1
59	85	6.9	6.8	5.4	5.3	4.3	4.5	4.5	4.0
60	90	-	-	4.1	4.2	3.4	3.6	4.0	3.2
		Non-white Female[1]							
61	0	64.4	63.7	62.7	59.6	49.5	46.9	37.7	35.0
62	1	66.1	65.5	64.4	58.5	52.3	50.4	45.2	43.5
63	5	62.6	62.1	60.9	55.4	49.8	48.7	46.4	46.0
64	10	57.8	57.3	56.2	50.8	45.3	44.5	42.8	43.0
65	15	53.0	52.5	51.4	46.1	40.9	40.4	39.2	39.8
66	20	48.3	47.8	46.8	42.0	37.2	37.2	36.1	36.9
67	25	43.7	43.3	42.4	38.2	33.9	34.4	33.0	33.9
68	30	39.3	38.9	38.0	34.4	30.7	31.5	29.6	30.7
69	35	35.0	34.7	33.8	30.7	27.5	28.6	26.4	27.5
70	40	30.9	30.6	29.8	27.2	24.3	25.8	23.3	24.4

Age		1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902
		Non-white Female[1] (concluded)							
71	45	26.9	26.8	26.1	23.9	21.4	22.6	20.4	21.4
72	50	23.4	23.2	22.7	21.0	18.6	19.8	17.7	18.7
73	55	20.3	20.2	19.6	18.4	16.3	17.1	15.0	15.9
74	60	17.4	17.4	17.0	16.1	14.2	14.7	12.8	13.6
75	65	14.7	14.8	14.5	13.9	12.2	12.4	10.8	11.4
76	70	12.9	12.9	12.3	11.8	10.4	10.3	9.2	9.6
77	75	10.8	10.8	10.2	9.8	8.6	8.4	7.6	7.9
78	80	9.1	9.1	8.2	8.0	6.9	6.6	6.1	6.5
79	85	7.6	7.3	6.2	6.4	5.5	5.2	5.1	5.1
80	90	-	-	4.1	5.0	4.2	4.1	4.5	4.0
		Total Population							
81	0	68.8	68.6	68.1	63.6	59.2	56.4	51.5	49.2
82	1	69.8	69.6	69.2	65.8	61.9	59.9	57.1	55.2
83	5	66.1	66.0	65.5	62.5	59.3	58.0	56.2	55.0
84	10	61.3	61.1	60.7	57.8	54.8	53.8	52.2	51.1
85	15	56.5	56.3	55.9	53.1	50.3	49.4	47.7	46.8
86	20	51.7	51.6	51.2	48.5	45.9	45.3	43.5	42.8
87	25	47.1	47.0	46.6	44.1	41.9	41.5	39.6	39.1
88	30	42.4	42.3	41.9	39.7	37.8	37.7	35.7	35.5
89	35	37.8	37.7	37.3	35.3	33.7	33.9	31.9	31.9
90	40	33.2	33.2	32.8	31.0	29.7	30.1	28.2	28.3
91	45	28.9	28.8	28.5	26.9	25.8	26.3	24.5	24.8
92	50	24.7	24.7	24.5	23.0	22.1	22.5	21.0	21.3
93	55	20.9	20.9	20.6	19.3	18.5	18.9	17.6	17.9
94	60	17.3	17.3	17.0	15.9	15.2	15.5	14.4	14.8
95	65	14.0	14.1	13.8	12.8	12.2	12.4	11.6	11.9
96	70	11.2	11.2	10.9	10.0	9.6	9.7	9.1	9.3
97	75	8.6	8.6	8.4	7.6	7.3	7.5	7.0	7.1
98	80	6.6	6.6	6.3	5.7	5.5	5.6	5.3	5.3
99	85	5.1	5.1	4.7	4.3	4.2	4.2	4.2	4.0

/1/ Figures for the non-white groups cover only Negroes, who never comprised less than 99% of the corresponding non-white population.

434. LIFE EXPECTANCY: MAN, VARIOUS NATIONS

Values are years.

	Nation	Years Upon Which Data Are Based	Expectation of Life at Birth	
			Male	Female
	Africa and Adjacent Areas			
1	Egypt	1936-1938	36.65	41.48
2	Mauritius[1]	1942-1946	32.25	33.83
3	S. Rhodesia (Europeans)	1935-1937	58.52	62.57
4	Union of South Africa (Europeans)	1945-1947	63.78	68.31
	America, North and Adjacent Areas			
5	Barbados	1945-1947	49.17	52.94
6	British Honduras	1944-1948	44.99	48.97
7	Canada	1947	65.18	69.05
8	Guatemala	1939-1941	35.97	37.09
9	Jamaica	1945-1947	51.25	54.58
10	Mexico	1940	37.92	39.29
11	Panama	1941-1943	50.34	53.46
12	Trinidad and Tobago	1945-1947	52.98	56.03
13	United States, White	1951	66.61	72.62
14	United States, Non-white	1951	59.37	63.71
	America, South and Adjacent Areas			
15	Brazil	1920	37.43[2]	
16	British Guiana	1945-1947	49.32	52.05
17	Chile	1939-1942	40.65	43.06
18	Venezuela	1941-1942	45.83	47.55
	Asia and Adjacent Areas			
19	Ceylon	1949	54.20	52.80
20	China (Formosa)	1936-1940	41.08	45.73
21	Cyprus	1931-1946	57.30	59.30
22	India	1931-1941	32.09	31.37
23	Israel	1951	67.30	70.10
24	Japan	1949-1950	56.19	59.61
25	Korea	1938	47.20	50.59
26	Thailand, Bangkok	1937-1938	36.73	43.30

	Nation	Years Upon Which Data Are Based	Expectation of Life at Birth	
			Male	Female
	Europe and Adjacent Areas			
27	Austria	1930-1933	54.50	58.50
28	Belgium	1946-1949	62.04	67.26
29	Bulgaria	1926-1928	45.92	46.64
30	Czechoslovakia	1929-1932	51.96	55.18
31	Denmark	1946-1950	67.80	70.10
32	Finland	1941-1945	54.62	61.14
33	France	1946-1949	61.90	67.40
34	Germany, Federal Republic	1950	64.06	67.92
35	Greece	1928-1930	49.09	50.89
36	Hungary	1941	54.92	58.22
37	Iceland	1931-1940	60.90	65.60
38	Ireland	1945-1947	60.47	62.43
39	Italy	1930-1932	55.76	56.00[3]
40	Luxembourg	1946-1948	61.69	65.75
41	Malta and Gozo	1946	55.69	57.72
42	Netherlands	1947-1949	69.40	71.50
43	Norway	1945-1948	67.76	71.68
44	Poland	1948	55.60	62.50
45	Portugal	1939-1942	48.58	52.82
46	Spain	1940	47.12	53.24
47	Sweden	1941-1945	67.06	69.71
48	Switzerland	1939-1944	62.68	66.96
49	United Kingdom: England and Wales	1951	65.84	70.88
	Northern Ireland	1936-1938	57.86	59.20
51	Scotland	1951	64.20	68.30
52	USSR (Europe)	1926-1927	41.93	46.79
	Oceania			
53	Australia	1946-1948	66.07	70.63
54	Hawaii	1919-1920	47.79	47.27
55	New Zealand (Europeans)	1947	67.77	71.62

/1/ Exclusive of island dependencies. /2/ Total persons. /3/ Value for 1935-1937 was 57.49.

435. AVERAGE LIFE SPAN: MAN, NORTH AMERICA[1]

Values are years.

	Period	White		Negro			Period	White		Negro	
		Male	Female	Male	Female			Male	Female	Male	Female
1	1850	38.20[2,3]	40.50[2,3]			7	1920-1929[5]	57.85	60.62	46.90	47.95
2	1890	42.50[2,3]	44.40[2,3]			8	1929-1931	59.12	62.67	47.55	49.51
3	1900-1902[4]	48.23	51.08	32.54	35.04	9	1930-1936[6,7]	60.62	64.52	50.06	52.62
4	1901-1910[4]	49.32	52.54	32.57	35.65	10	1939-1941[6]	62.81	67.29	52.26	55.56
5	1909-1911[4]	50.23	53.62	34.05	37.67	11	1949[6]	65.88	71.51	58.57	62.93
6	1919-1921[5]	56.34	58.53	47.14	46.92	12	1951[6]	66.61	72.62	59.37	63.71

/1/ Increase in life expectancy at birth is mainly caused by decreased infant mortality; expectancy from age 30 was only about 6 years greater in 1949 than in 1850, and expectancy at age 60 was no greater in 1949 than in 1850. /2/ Massachusetts. /3/ Non-whites includes, about 1% of the total. /4/ Original death registration states. /5/ Death registration states in 1920. /6/ Continental United States. /7/ All non-whites.

436. POPULATION, ESTIMATED: VARIOUS WORLD REGIONS

Part I: WORLD POPULATION BY CONTINENTS AND REGIONS

Values in parentheses are ranges.

	Continent and Region	Estimates of Midyear Population, Millions[1]					Area[2] sq km x 1000	Population Density, 1953 per sq km
		1920	1930	1940	1950	1953		
1	World total[3]	1813	1987	2213	2455	2547	135,168	19
2		(1753-1872)	(1937-2036)	(2157-2270)	(2370-2540)	(2459-2634)		
3	Africa, total	140	155	172	198	208	30,310	7
4		(130-151)	(145-164)	(163-181)	(190-207)	(199-216)		
5	Northern Africa	46	51	57	65	68	10,246	7
6		(40-53)	(45-56)	(52-62)	(60-69)	(63-72)		
7	Tropical and Southern Africa	94	104	115	134	140	20,064	7
8		(88-100)	(98-110)	(110-121)	(128-139)	(134-146)		
9	America, total	208	244	277	330	351	42,097	8
10		(204-212)	(240-247)	(274-280)	(326-334)	(347-355)		
11	North America	117	135	146	160	171	21,482	8
12		(115-118)	(134-136)	(145-147)	(167-169)	(176-179)		
13	Central America	30	34	41	51	55	2760	20
14		(29-31)	(33-35)	(40-42)	(50-52)	(54-56)		
15	South America	61	75	90	111	119	17,855	7
16		(59-64)	(72-77)	(88-92)	(108-114)	(116-122)		
17	Asia, total (except USSR)[4]	970	1047	1176	1321	1364	27,003	51
18		(922-1019)	(1007-1087)	(1128-1224)	(1247-1394)	(1288-1439)		
19	Southwest Asia	44	48	54	62	66	5543	12
20		(38-50)	(43-52)	(50-58)	(58-66)	(61-70)		
21	South Central Asia	326	362	410	464	482	5143	94
22		(320-333)	(355-369)	(403-417)	(459-470)	(476-488)		
23	Southeast Asia	110	128	155	171	179	4456	40
24		(106-113)	(125-132)	(151-160)	(165-176)	(173-186)		
25	East Asia	490	509	557	624	637	11, 861	54
26		(469-531)	(476-542)	(517-597)	(558-690)	(570-705)		
27	Europe, total (except USSR)[4]	328	355	380	393	402	4930	82
28		(325-330)	(353-357)	(378-382)	(391-395)	(400-404)		
29	Northern and Western Europe	115	122	128	133	136	2252	60
30		(114-116)	(122-123)	(127-128)	(133-134)	(135-136)		
31	Central Europe	112	120	127	128	131	1014	129
32		(111-114)	(118-121)	(126-129)	(127-129)	(130-131)		
33	Southern Europe	101	113	125	131	135	1664	81
34		(99-102)	(112-114)	(124-126)	(130-133)	(134-136)		
35	Oceania	8.8	10.4	11.3	13.0	14.0	8557	2
36		(8.6-9.1)	(10.2-10.7)	(11.1-11.5)	(12.8-13.2)	(13.8-14.2)		

/1/ Estimates include adjustments for under-enumeration of various censuses. /2/ Land area including inland waters but excluding certain uninhabited polar regions and islands. /3/ Including allowance for the population and area of the USSR. /4/ European Turkey is included with Asia.

Part II: ESTIMATES OF TOTAL POPULATION: NORTH AMERICA, 1920-1954

	Geographical Area	Estimated Population, Thousands									
		1920	1930	1940	1945	1950	1951	1952	1953	1954	
1	Alaska[1], total	55	60	75	139	137	161	191	205		
2	Civilian population			74	79	111	123	141	155		
3	Bahama Islands		61	70	71	79	81	83	85		
4	Barbados		159	168	187	209	212	216			
5	Bermuda[2]	22[3]	32	32	35	37	38	39			
6	British Honduras	44[3]	51	56	59	67	70	72	75		
7	Canada[4]	8820	10,484	11,682	12,394	13,712	14,009	14,430	14,781	15,195	
8	Excluding Yukon and N.W. Territories	8543[5]	10,195[5]	11,364[5]	12,055[5]	13,688	13,984	14,405	14,756		
9	Newfoundland	264	276	301	322						
10	Yukon and N.W. Territories	13	13	17	17	24	25	25	25		
11	Canal Zone, Panama, total[1]	23	40	57	88	53	56	58	57		
12	Civilian population			31	46	42	42	42	42		
13	Costa Rica	421[3]	499	619	695	800	825	850	881	915	
14	Cuba[6]			4566	4940	5362	5471		5807		
15	Dominican Republic	879	1256	1674	1889	2131	2183	2236	2291	2347	
16	El Salvador	1168	1443	1633	1742	1868	1920	1986	2052	2122	
17	Greenland[7]	14	16	19	21	23	24	25	25		
18	Guatemala	1314[3]	1771	2222	2444	2802	2890	2975	3049		
19	Honduras		948	1146	1261	1428	1470	1513	1564		
20	Jamaica	830	997	1183	1266	1403	1430	1457	1486		
21	Cayman Islands		6	7	7	7	7	8			
22	Turks and Caicos Islands		5	6	6	7					
23	Leeward Islands		86	99	107	112	116	119	121		
24	Antigua		30	34	41	45	46	48	49		
25	Montserrat		13	15	15	14	14	13	13		
26	St. Kitts-Nevis and Anguilla		38	43	45	48	49	51	52		
27	Virgin Islands (British)		5	7	6	6	7	7	7		
28	Mexico[8]		16,589	19,763	22,233	25,791	26,332	26,992	28,053	28,850	
29	Netherlands Antilles	55	72	107	131	161	166	172	178		
30	Nicaragua			825	923	1060	1093	1128	1166	1202	
31	Panama[9]	447	471	620	703	797	821	841	863		
32	Puerto Rico[1]	1312	1552	1880	2099	2207	2233	2240	2229		
33	Civilian population			1876	2068	2202	2214	2214	2201		
34	St. Pierre and Miquelon				4		5	5			
35	Trinidad and Tobago		405	476	547	632	649	663	678	698	
36	United States[9]		123,188	132,122	139,928	151,683	154,360	157,022	159,629	162,414	
37	Excluding armed forces abroad	106,466	123,077	131,954	132,481	151,234	153,384	155,755	158,306		
38	Virgin Islands (USA)[1]		22	25	27	27	25	24	25		
39	Windward Islands[1] (Dominica Grenada, St. Lucia, St. Vincent)			259	263	276	284				

/1/ Legal population, but including U.S. Armed Forces stationed in the area. /2/ Civilian population, excluding tourists. /3/ For 31 December. /4/ Legal population. /5/ Prior to 1950, also excluding Newfoundland, which became the 10th province on 1 April 1949. /6/ Estimates for last intercensal period not yet revised to accord with census results. /7/ Indigenous population, representing approximately 98% of the total. /8/ Excluding Canal Zone shown separately above. /9/ Legal population, but excluding civilian citizens of continental U.S. absent from the country for extended periods of time.

437. POPULATION, PER CENT DISTRIBUTION BY AGE:

U.S.A., 1850-1950

	Age (yr)	1950	1940	1930	1920	1910	1900	1890	1880	1870	1860	1850
1	<5	10.7	8.0	9.3	10.9	11.6	12.1	12.2	13.6	14.3	15.4	15.1
2	5-9	8.8	8.1	10.3	10.8	10.6	11.7	12.1	12.9	12.5	13.3	14.0
3	10-14	7.4	8.9	9.8	10.1	9.9	10.6	11.2	11.4	12.4	11.8	12.5
4	15-19	7.0	9.4	9.4	8.9	9.9	9.9	10.5	10.0	10.5	10.7	10.9
5	20-24	7.6	8.6	8.9	8.8	9.8	9.7	9.9	10.1	9.7	18.2	12.6
6	25-29	8.1	8.4	8.0	8.6	8.9	8.6	8.3	8.1	8.0		
7	30-34	7.6	7.8	7.6	7.6	7.6	7.3	7.3	7.1	7.6	12.8	12.2
8	35-39	7.5	7.2	7.5	7.4	7.0	6.5	6.2	6.0	6.0		
9	40-44	6.8	6.7	6.5	6.0	5.7	5.6	5.1	4.9	5.0		
10	45-49	6.0	6.3	5.7	5.5	5.4	4.9	4.5	4.4	4.2	8.3	8.0
11	50-54	5.5	5.5	4.9	4.5	4.2	3.9	3.7	3.7	3.5		
12	55-59	4.8	4.4	3.8	3.4	3.0	2.9	2.7	2.5	2.3	5.0	4.8
13	60-64	4.0	3.6	3.1	2.8	2.5	2.4	2.3	2.2	2.0		
14	65-69	3.3	2.9	2.3	2.0	1.8	1.7	1.6	1.4	1.3	2.8	2.6
15	70-74	2.3	2.0	1.6	1.3	1.2	1.2	1.1	1.0	0.9		
16	>74	2.2	2.0	1.6	1.4	1.3	1.2	1.1	1.0	0.8	1.4	1.5
17	Not reported			0.1	0.1	0.2	0.3	0.3			0.2	0.1

438. POPULATION, MALE-FEMALE RATIO, U.S.A., 1790-1950

Values are number of males per 100 females.

	Census Year	All Classes	White	Negro	Other Races
1	1950	98.6	99	94.3	131.7
2	1940	100.7	101.2	95	140.5
3	1930	102.5	102.9	97	150.6
4	1920	104	104.4	99.2	156.6
5	1910	106	106.6	98.9	185.7
6	1900	104.4	104.9	98.6	185.2
7	1890	105	105.4	99.5	182.5
8	1880	103.6	104	97.8	362.2
9	1870	102.2	102.8	96.2	400.7?
10	1860	104.7	105.3	99.6	260.8
11	1850	104.3	105.2	99.1	
12	1840	103.7	104.5	99.5	
13	1830	103.1	103.8	100.3	
14	1820	103.3	103.2	103.4	
15	1810		104		
16	1800		104		
17	1790		103.8		

439. POPULATION, LIVE BIRTHS AND BIRTH RATES, BY RACE: U.S.A., 1915-1954

Population estimated as of July 1 for 1916-1939, 1942-48 and 1952, and enumerated as of April 1 for 1940 and 1950. Rates are per 1000 population in each specified group.

	Year	Population of Continental United States[4]	Number of States[4]	Population[5]	Birth Registration State[2]			Births Adjusted for Under-registration[3] United States			
					Registered Births			Birth Rates[5]		Number		Rates[6]	
					Total	White	Non-white	Total	White	White	Non-white	White	Non-white
1	1954	162,414,000	48	161,195,000	4,021,000			24.9					
2	1953[8]	159,629,000	48	158,306,000	3,902,120	3,356,772	545,348	24.8	23.7	32.3	3,389,000	575,000	24.0	34.1
3	1952[8]	157,028,000	48	155,755,000	3,844,986	3,302,658	524,328	24.7	23.9	31.8	3,356,000	555,000	24.1	33.6
4	1951[8]	154,360,000	48	153,384,000	3,750,850	3,237,072	513,778	24.5	23.6	31.8	3,277,000	546,000	23.9	33.8
5	1950	151,132,000	48	150,697,361	3,554,149	3,063,627	490,522	23.6	22.7	31.1	3,108,000	524,000	23.0	33.3
6	1949	149,188,000	48	148,665,000	3,559,529	3,083,721	475,808	23.9	23.2	30.6	3,136,000	513,000	23.6	33.0
7	1948	146,631,000	48	146,093,000	3,535,068	3,080,316	454,752	24.2	23.5	29.8	3,141,000	495,000	24.0	32.4
8	1947	144,126,000	48	143,446,000	3,699,940	3,274,620	425,320	25.8	25.5	28.3	3,347,000	469,000	26.1	31.2
9	1946	141,389,000	48	141,389,000	3,226,672	2,913,645	375,027	25.3	23.0	25.3	2,990,000	420,000	23.6	28.4
10	1945	139,928,000	48	139,928,000	2,735,456	2,395,563	339,893	19.5	19.1	23.2	2,471,000	388,000	19.7	26.5
11	1944	138,397,000	48	138,397,000	2,794,800	2,454,700	340,100	20.2	19.8	23.6	2,545,000	394,000	20.5	27.4
12	1943	136,739,000	48	136,739,000	2,934,860	2,596,763	340,097	21.5	21.2	24.1	2,704,000	400,000	22.1	28.3
13	1942	134,860,000	48	134,860,000	2,808,996	2,486,934	322,062	20.8	20.6	23.2	2,605,000	384,000	21.5	27.7
14	1941	133,402,000	48	133,402,000	2,513,427	2,204,903	308,524	18.8	18.4	22.6	2,330,000	374,000	19.5	27.3
15	1940	131,820,000	48	131,669,275	2,360,399	2,067,763	292,666	17.9	17.5	21.7	2,199,000	360,000	18.6	26.7
16	1939	130,879,718	48	130,879,718	2,265,588	1,982,671	282,917	17.3	16.9	21.2	2,177,000	349,000	18.0	26.1
17	1938	129,824,939	48	129,824,939	2,286,962	2,005,955	281,007	17.6	17.2	21.2	2,146,000	348,000	18.4	26.3
18	1937	128,824,829	48	128,824,829	2,203,337	1,928,437	274,900	17.1	16.7	20.9	2,071,000	342,000	17.9	26.0
19	1936	128,053,180	48	128,053,180	2,144,790	1,881,883	262,907	16.7	16.4	20.1	2,027,000	328,000	17.6	25.1
20	1935	127,250,232	48	127,250,232	2,155,105	1,886,012	267,093	16.9	16.5	20.6	2,042,000	334,000	17.9	25.8
21	1934	126,373,773	48	126,373,773	2,167,636	1,898,501	269,135	17.2	16.7	20.9	2,058,000	338,000	18.1	26.3
22	1933	125,578,763	48	125,578,763	2,081,232	1,823,531	257,701	16.6	16.2	20.2	1,982,000	325,000	17.6	25.5
23	1932	124,840,477	47	118,903,899	2,074,042	1,822,425	251,617	17.4	17.0	21.3	2,099,000	341,000	18.7	26.9
24	1931	124,039,648	46	117,455,229	2,112,760	1,867,245	245,515	18.0	17.7	21.0	2,170,002	335,000	19.5	26.9
25	1930	123,076,741	46	116,544,946	2,203,958	1,953,163	250,795	18.9	18.6	21.6	2,274,000	344,000	20.6	27.5
26	1929	121,769,939	46	115,317,450	2,169,920	1,924,475	245,445	18.8	18.5	21.3	2,244,000	339,000	20.5	27.3
27	1928	120,501,115	44	113,636,160	2,233,149	1,982,246	250,903	19.7	19.4	22.1	2,325,000	349,000	21.5	28.5
28	1927	119,038,062	40	104,320,830	2,137,836	1,925,585	212,251	20.5	20.2	23.6	2,425,000	377,000	22.7	31.1
29	1926	117,399,225	35	90,400,590	1,856,068	1,707,034	149,034	20.5	20.2	25.0	2,441,000	398,000	23.1	33.4
30	1925	115,831,963	33	88,294,564	1,878,880	1,731,669	147,211	21.3	21.0	25.4	2,506,000	403,000	24.1	34.2
31	1924	114,113,463	33	87,000,295	1,930,614	1,762,872	167,742	22.2	21.9	26.3	2,577,000	401,000	25.1	34.8
32	1923	111,949,945	30	81,072,433	1,792,646	1,644,036	148,612	22.1	21.9	25.3	2,531,000	380,000	25.2	33.2
33	1922	110,054,778	30	79,560,746	1,774,911	1,629,387	145,524	22.3	22.1	25.3	2,507,000	375,000	25.4	33.2
34	1921	108,541,489	27	70,807,090	1,714,261	1,565,446	148,815	24.2	23.9	27.6	2,657,000	398,000	27.3	35.8
35	1920	106,466,420	23	63,597,307	1,508,874	1,395,123	113,751	23.7	23.5	27.0	2,566,000	383,000	26.9	35.0
36	1919	105,062,747	22	61,212,076	1,373,438	1,269,363	104,075	22.4	22.3	24.9	2,387,000	353,000	25.3	32.4
37	1918	104,549,886	20	55,153,782	1,363,649	1,288,711	74,938	24.7	24.8	24.3	2,588,000	360,000	27.6	33.0
38	1917	103,413,743	20	55,197,952	1,353,792	1,280,288	73,504	24.5	24.5	24.3	2,587,000	357,000	27.9	32.9
39	1916	101,965,984	11	32,994,013	818,983			24.9						
40	1915	100,549,013	10	31,096,697	776,304			25.0						

/1/ Estimates of armed forces overseas are included in the years 1918, 1940-1954. /2/ Effective 1934, all of continental United States included. /3/ Adjustments on the basis of 48 states for lines 12 through 20. /4/ District of Columbia not included in the "Number of States," though represented in all data shown for each year. /5/ For 1942-46, estimates of population include armed forces overseas; rates based on population, including armed forces overseas. /6/ For 1917-19 and 1941-46 based on population including armed forces overseas. /7/ Tentative. /8/ Based on births from a 50% sample.

Values are males per 100 individuals. Values in parentheses are estimates "b" of the 95% range, unless otherwise indicated by superscripts (cf Introduction). Adult values should be considered with caution (particularly those for Invertebrates) because of extreme variation caused by geographical area, species considered, time of year, and population conditions.

	Species	At Birth	Adult
	Mammalia		
1	Man, white, U.S.A.[1]	51.39	
2	Man, non-white, U.S.A.[1]	50.28	
3	Ass (Equus asinus)	49(32-66)	
4	Badger (Meles meles)		54(34-75)
5	Bat, big brown (Eptesicus fuscus)		68(32-78)[d]
6	Bat (Myotis sodalis)		51(49-53)
7	Bat (Pipistrellus subflavus)		74(68-80)
8	Beaver (Castor canadensis)		52(45-59)
	Cattle (Bos taurus)		
9	Single birth	52(43-58)[d]	
10	Twin birth	49	
11	Triplet birth	46	
12	Ayrshire	49(45-53)	
13	Brown alpine	50(47-52)	
14	Guernsey	44(41-48)	
15	Hereford	51(49-53)	
16	Holstein	49(47-50)	
17	Jersey	52(48-56)	
18	Shorthorn	49(47-51)	
19	Welsh, black	50(48-52)	
20	Zebu	51(50-52)	
	Dog (Canis familiaris)		
21	Collie, St. Bernard, spaniel	54(53-55)	
22	German shepherd	55(51-58)[d]	
23	Greyhound	52(51-54)	
24	Schnauzer	51(49-53)	
25	Terrier	56(53-59)	
26	Elk, North American	51(46-56)[d]	
27	Fox, red	50(41-59)	52(46-56)[d]
28	Fox, silver	53(51-55)	
29	Goat, Angora	50(48-52)[d]	
30	Goat, crossbreeds	51(48-54)	
31	Goat, Saanen (Britain)	55(50-61)	
32	Goat, Toggenburg	50(46-55)	
33	Guinea pig (Cavia porcellus)	52(51-53)[d]	
34	Hare (Lepus americanus)		54(52-56)
35	Horse (Equus caballus)	52(50-55)[d]	
36	Horse, Thoroughbred	50	
37	Mink, ranch (Mustela spp)	51(49-53)[d]	
38	Mink, hybrid, pastel	50(48-52)	
39	Mole (Scalopus aquaticus)		58(55-60)
40	Mouse (Mus musculus)		52(50-54)[d]
41	Mouse, albino	50(48-52)[d]	
42	Mouse, Japanese and waltzing	51(48-52)[d]	
43	Mule	44(42-47)[d]	
44	Muskrat (Ondatra zibethica)	54(42-66)[d]	56(55-57)[d]
45	Opossum (Didelphis marsupialis)	57	57(50-68)[d]
46	Rabbit (Oryctolagus spp)	50(49-51)[d]	
47	Rabbit, Flemish giant	57(46-68)[d]	
48	Rabbit, Polish	51(45-56)[d]	
49	Raccoon (Procyon lotor)		52(46-58)[d]
50	Rat (Rattus norvegicus)	50(49-51)[d]	
51	Rat, albino	50(49-51)	
52	Rat, brown	51(48-55)	41(40-42)[d]
53	Rat, hybrid and piebald	51(50-52)	
54	Seal, harbor (Phoca groenlandica)		51(48-54)
	Sheep (Ovis aries)		
55	Single birth	50(44-55)[d]	
56	Twin and triplet birth	49	
57	Quadruplet birth	43	
58	Cheviot	49(48-50)	
59	Karakul	52(47-57)	
60	Merino	47(44-50)	
61	Navajo	49(48-50)	
62	Swine (Sus scrofa)	52(51-53)[d]	
63	Berkshire	51(50-52)	
64	Duroc, Jersey	49(48-50)	
65	German improved	51(50-52)[d]	
66	Inbred and linecross non-inbred	52(51-53)	
67	Weasel (Mustela nivalis)		73(63-83)
	Aves		
68	Canary (Serinus spp)	44(36-51)[d]	
69	Cuckoo (Cuculus spp)		55(52-58)
70	Crow (Corvus brachyrhynchos)		56
71	Dove (Zenaidura macroura)	52(50-54)	60(57-63)
72	Duck (Anas spp)	50(49-52)	
73	Canvasback	51(47-55)[d]	
74	Mallard	53(49-57)[d]	52(48-56)[d]
75	Pintail	53(49-57)[d]	66(64-69)[d]
76	Redhead	53(48-58)[d]	
77	Fowl (Gallus spp)	49(47-51)[d]	
78	Rhode Island Red	50(46-54)	
79	White Leghorn	49(48-51)	
80	Grackle (Quiscalus spp)		30(26-35)[d]
81	Grouse, ruffed (Bonasa sp)	52(47-56)[d]	58(52-61)[d]
82	Grouse, sage		50(48-52)[d]
83	Grouse, sharp-tailed		63(54-72)[d]
84	Hawk (Buteo spp)		50(46-54)
85	Parrot (Psittacus spp)		57(50-63)
86	Partridge (Perdix spp)	43(38-48)[d]	60(58-62)[d]
87	Pheasant, ring-necked (Phasianus sp)	50(46-54)[d]	52(50-55)
88	Pigeon (Columba spp)	50(48-52)[d]	
89	Quail, bobwhite (Colinus sp)		(59-66)
90	Quail, California (Lophortyx sp)		58(54-62)[d]
91	Redwing (Agelaius sp)		77(73-81)
92	Sparrow (Melospiza melodia)		52
93	Starling (Sturnus spp)		68
94	Turkey (Melesgris gallopavo)		50(48-55)
	Reptilia		
95	Lizards		58(55-62)
96	Snakes		50(48-52)
97	Tortoises, turtles		43(38-48)
	Amphibia		
98	Frogs, toads		45(43-47)
99	Salamanders, newts		56(51-61)
	Pisces		
100	Elasmobranchs		47(45-48)
101	Sturgeons and spoonbills		17(8-26)
	True bony fishes		
102	Minnow (Gambusia holbrookii)	50(48-53)	
103	Walleye (Stezostedon vitreum)		72
	Arthropoda		
	Crustacea		
104	Amphipoda		38(35-40)
105	Cladocera		20(18-22)
106	Copepoda		28(27-29)
107	Cumacea		37(29-45)
108	Decapoda		55
109	Isopoda		33(31-35)
110	Myriopoda		31(28-33)
111	Ostracoda		39(35-43)
112	Phyllopoda		28(27-29)
113	Stomatopoda		44(36-52)
114	Xiphura		49(32-66)
	Insecta		
115	Anoplura and Mallophaga		(40-50)[d]
116	Coleoptera		77
117	Diptera		43(42-45)
118	Diptera (Drosophila melanogaster)		46
119	Hemiptera		12(11-13)
120	Lepidoptera		53(52-54)
121	Odonata		77(74-81)
122	Orthoptera		44(43-45)
123	Strepsiptera		65(62-68)
124	Thysanoptera		12(10-13)
125	Thysanura		64(46-82)
126	Arachnida		48(46-49)
127	Pycnogonida		36(35-38)
	Mollusca		
128	Cephalopoda		46(43-49)
129	Gastropoda		47(46-48)
130	Pelecypoda		50(49-51)
	Trochelminthes		
131	Rotifera		33(32-34)
	Coelenterata		
132	Placophora		53(52-54)

[1] Values based on 50% sample of 1952 registered live births.

Part I: FIELD CROPS

Where plant part or product is specified, acreage values apply to the plants grown for the yield of that part or product.

	Crop Plant	Acreage Harvested				Yield per Acre			
		1930-1939[1]	1940-1949[1]	1950	1953	1930-1939[1]	1940-1949[1]	1950	1953
		Thousands of Acres[2]				Pounds[3]			
1	Alfalfa (Medicago sativa), seed	556	881	927	939	112	92	113	145
2	Barley (Hordeum vulgare), grain	10,707	12,569	11,153	8534	989	1172	1306	1354
3	Bean, edible (Phaseolus spp)[4]	1716	1882	1512	1398	781[5]	958[5]	1117[5]	1296[5]
4	Beet, sugar (Beta vulgaris)	815	750	925	745	2280	26,200	29,200	32,400
5	Buckwheat (Fagopyrum esculentum), grain	460	405	253	175	800	870	840	874
6	Clover, alsike (Trifolium hybridium), seed	172	132	96	63	119	153	146	192
7	Clover, red (T. pratense), seed	947	1755	2556	1415	105	56	58	59
8	Corn, all (Zea mays)	98,049	87,882	81,817	80,279	1316[5]	1898[5]	2094[5]	2218[5]
9	Cotton (Gossypium spp), lint	31,223	21,662	17,843	24,340	295	268	269	324
10	Cowpea (Vigna spp), peas	1140	854	420	318	384[5]	342[5]	390[5]	372[5]
11	Flaxseed (Linum spp)	1788	3919	4090	4380	358	526	549	470
12	Hay, all types	67,893	74,845	74,368	73,918	2300	2720	2760	2840
13	Hop,(Humulus spp), grain	30	37	39	28	1171	1267	1508	1488
14	Lespedeza (Lespedeza spp), seed	361	885	746	445	173	216	192	143
15	Oat (Avena sativa), grain	36,487	39,460	40,733	39,358	874	1062	1107	989
16	Peanut (Arachis hypogaea)	1486	2923	2268	1541	714[6]	704[6]	898[6]	1031[6]
17	Pea, field (Pisum sativum)	261	471	233	262	1008[5]	1230[5]	1376[5]	1279[5]
18	Rice (Oryza sativa), rough	942	1507	1620	2135	2178	2083	2388	2460
19	Rye (Secale cereale), grain	3320	2448	1744	1382	627	683	683	728
20	Sorghum (Sorghum spp), grain	7564	6737	10,335	6137	553	875	1266	997
21	Soybean (Glycine soja), bean	2052	9348	13,814	14,366	966[5]	1140[5]	1302[5]	1098[5]
22	Sugar cane (Saccharum officinarum), sirup	137	108	49	27	1809	1975	2134	2372
23	Sugar cane (S. officinarum), sugar	257	306	333	346	36,000	38,800	41,600	44,200
24	Sweetclover (Melilotus alba), seed	279	258	547	226	185	161	156	151
25	Timothy (Phleum pratense), seed	483	354	445	197	149	158	142	134
26	Tobacco (Nicotiana tabacum), leaves	1676	1613	1599	1634	834[7]	1100[7]	1269[7]	1259[7]
27	Velvetbean (Stizolobium spp)	1970	1486	580	311	806[8]	824[8]	890[8]	823[8]
28	Wheat, all (Triticum aestivum), grain	55,883	62,625	61,610	67,608	798	1026	990	1050
29	Wheat, winter (T. aestivum), grain	39,141	44,640	43,253	46,681	864	1,062	1,026	1128

/1/ Data applicable to 10-year averages. /2/ Acres x 0.4047 = hectares. /3/ Pounds per acre x 1.121 = kg per hectare. /4/ Besides the ordinary edible beans (kidney and lima) and beans grown for seed, data include blackeyes and garbonzos in California. /5/ Shelled. /6/ Picked and threshed. /7/ Farm sales-weight basis. /8/ Not shelled.

Part II: FRUIT AND VEGETABLE CROPS

	Crop Plant	Acreage Harvested				Yield per Acre			
		1930-1939[1]	1940-1949[1]	1950	1953	1930-1939[1]	1940-1949[1]	1950	1953
		Thousands of Acres[2]				Thousands of Pounds[3]			
1	Apple (Pyrus malus)[4]	1252[5]	884	817		5.6[5]	5.9	7.2	
2	Asparagus (Asparagus officinalis)	112	127	131	135	2.2	2.5	2.5	2.2
3	Avocado (Prunus gratissima)	9.5	15.3[6]			1.5	2.4[6]		
4	Bean, lima (Phaseolus lunatus macrocarpus)[7]	49	88	120	128	2.2[8]	2.5[8]	3.2[8]	3.7[8]
5	Bean, string (P. vulgaris)[9]	213	293	306	296	2.7	3.1	3.5	3.8
6	Beet, garden (Beta vulgaris)	19	28	30	25	10.4[10]	13.1[10]	15.3[10]	15.9[10]
7	Cabbage (Brassica oleracea capitata)	176	192	186	169	13.3	14.6	17.5	17.1
8	Cantaloupe (Cucumis melo)[11]	108	109	134	141	6.7	6.9	7.6	7.8
9	Carrot (Daucus carota)	42	73	94	82	15.8[10]	16.8[10]	17.1[10]	19.0[10]
10	Cauliflower (Brassica oleracea botrytis)[12]	30	35	33	30	9.6	11.3	13.8	15.8
11	Celery (Apium graveolens)	37	41	36	37	26	31	37.2	39.1
12	Cherry (Prunus spp)	101	107[6]	29	26	2.8	3.6[6]		
13	Corn, sweet (Zea mays saccharata)[13]	319	465	557	718	4.2[14]	4.9[14]	5.5[14]	5.9[14]
14	Cucumber (Cucumis sativus)	127	160	158	200	3.7	4.2	4.2	5.1
15	Fig (Ficus carica), from California	42	35	29	26	5.8	6.7	5.8	6.5
16	Grape (Vitis spp)	680	627[6]			6.6	8.8[6]		
17	Grapefruit (Citrus paradisi)	154	193	175	146	12.3	20.6	21.2	26.5
18	Lemon (C. limonia), from California	43	61	54	55	15.6	16.7	19.5	22.8
19	Lettuce (Lactuca sativa)	159	173	227	210	8.8	11.6	11.7	13.4
20	Onion (Allium cepa)	128	130	136	132	11.9	14.6	16.9	18.7
21	Orange (Citrus spp)	426	539	562	564	10.5	15.3	18.7	20
22	Pea, garden (Pisum sativum)[7]	370	474	442	443	3.2[8]	5.2[8]	5.1[8]	5.3[8]
23	Peach (Prunus persica)	639	646[6]			4.2	5.2[6]		
24	Pear (Pyrus communis)	220	178[6]			6.1	8.4[6]		
25	Potato (Solanum tuberosum)	3238	2515	1696	1508	6.8	10.1	15.2	14.9
26	Prune (Prunus domestica)	224	183[6]			6.2	6.6[6]		
27	Spinach (Spinacia oleracea)	79	99	81	69	4.0	4.1	5.1	6.1
28	Strawberry (Fragaria spp)	170	121	127	112	2.3	2.6	3.1	4.0
29	Sweetpotato (Ipomoea batatas)	845	641	492	350	4.6	5.0	5.6	5.3
30	Tomato (Lycopersicon esculentum)	562	739	581	528	7.5	10.0	12.1	15.7
31	Watermelon (Citrullus vulgaris)	256	250	374	435	6.7	7.2	6.4	6.2

/1/ Data applicable to 10-year averages, unless otherwise specified. /2/ Acres x 0.4047 = hectares. /3/ Pounds per acre x 1.121 = kg per hectare. /4/ Commercial orchards only. /5/ Average for 1934-1939. /6/ Average for 1940-1946. /7/ Immature seeds. /8/ Not shelled. /9/ Immature edible pods. /10/ Without tops. /11/ Data include Casaba and Persian melons but not honey balls and honey dews. /12/ Data include headed types. /13/ Commercial crops used for processing. /14/ In husk.

442. SPECIFIED NOTIFIABLE DISEASES, REPORTED CASES AND DEATHS: U.S.A., 1945-1954

Data for 1949-1954 classified according to the Sixth Revision of the International List (1948); for 1945-1948 data classified according to the Fifth Revision of the International List (1938).

(-) = data not available.

	Disease		1954	1953	1952	1951	1950	1949	1948	1947	1946	1945
1	Amebiasis	Cases	3523	4444	4280	3550	4568	5543	4871	3365	4093	3412
2		Deaths	131	129	136	148	136	164	113	155	182	185
3	Anthrax	Cases	22	45	47	60	49	54	60	69	40	40
4		Deaths	0	0	3	3	5	0	5	3	7	6
5	Botulism	Cases	18	18	18	33	20	24	39	46	(-)	(-)
6		Deaths	14	17	14	31	16	22	(-)	(-)	(-)	(-)
7	Brucellosis (undulant fever)	Cases	1823	2032	2537	3139	3510	4235	4991	6321	5887	5049
8		Deaths	15	18	23	34	36	68	55	58	69	94
9	Dengue	Cases	5	8	5	16	26	46	24	35	40	106
10		Deaths	0	0	0	0	0	2	0	0	1	0
11	Diphtheria	Cases	2041	2355	2960	3983	5796	7969	9493	12,262	16,354	18,675
12		Deaths	145	156	217	302	410	574	634	799	1259	1598
13	Dysentery, bacillary (shigellosis)	Cases	13,846	16,533	23,197	32,215	23,367	29,080	23,753	17,048	24,286	34,943
14		Deaths	243	337	334	356	335	498	364	273	309	506
15	Encephalitis, acute infectious	Cases	2,606	1935	1912	1123	1135	903	730	785	728	785
16		Deaths	407	386	471	429	394	465	570	630	642	735
17	Hepatitis, infectious and serum	Cases	50,093	33,700	31,428	7349	2820	2027	709	1092	(-)	(-)
18		Deaths	821	821	794	675	552	560	(-)	(-)	(-)	(-)
19	Leprosy	Cases	56	60	57	57	44	41	63	56	43	40
20		Deaths	4	7	4	3	3	4	21	16	16	27
21	Leptospirosis	Cases	48	42	62	13	30	21	18	15	(-)	(-)
22		Deaths	14	17	12	13	16	21	13	15	13	31
23	Malaria	Cases	715	1310	7023	5600	2184	4151	9606	15,116	46,610	62,763
24		Deaths	24	32	25	64	76	118	170	214	341	443
25	Measles	Cases	682,720	449,146	683,077	530,118	319,124	625,281	615,104	222,375	695,843	146,013
26		Deaths	518	462	618	683	468	949	888	472	1310	307
27	Meningococcal infections	Cases	4436	5077	4884	4164	3788	3519	3376	3420	5693	8208
28		Deaths	1015	1325	1386	1124	974	917	873	917	1257	1728
29	Plague	Cases	0	0	0	0	3	3	0	1	0	1
30		Deaths	0	0	0	0	1	1	0	1	0	0
31	Poliomyelitis, acute	Cases	38,476	35,592	57,879	28,386	33,300	42,033	27,726	10,827	25,898	13,624
32		Deaths	1368	1450	2145	1551	1904	2720	1895	580	1845	1186
33	Psittacosis and ornithosis	Cases	563	169	135	25	26	35	32	27	26	27
34		Deaths	3	4	5	1	0	0	0	1	2	0
35	Q fever	Cases	8	4	7	8	0	2	1	0	(-)	(-)
36		Deaths	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
37	Rabies in man[1]	Cases	12	12	24	18	18	10	24	26	34	43
38		Deaths	13	12	24	18	18	10	24	26	34	43
39	Rabies in animals[2]	Cases	7297	8903	8445	8008	7901	7587	8495	8920	10,850	9928
40		Deaths	(-)	8903	8445	8008	7901	7587	8495	8920	10,850	9928
41	Rocky Mountain spotted fever	Cases	294	313	327	347	464	570	547	596	587	472
42		Deaths	10	21	20	26	31	36	94	105	124	128
43	Salmonellosis, paratyphoid fever	Cases	5375	3946	2596	1773	1233	1243	882	951	723	649
44		Deaths	48	72	42	31	43	37				
45	Scarlet fever and streptococcal	Cases	147,785	132,935	113,677	84,151	64,494	87,220	91,295	93,595	125,511	185,570
46	sore throat	Deaths	262	295	351	347	346	486	460	514	754	1094
47	Smallpox	Cases	93	4	21	11	39	49	57	176	337	346
48		Deaths	0	1	0	1	1	2	5	5	25	12
49	Tetanus	Cases	524	506	484	506	486	579	601	560	(-)	(-)
50		Deaths	332	337	360	394	336	398	506	511	585	653
51	Trachoma	Cases	1172	773	3088	2916	1584	1475	2565	1540	(-)	(-)
52		Deaths	1	0	0	0	0	0	(-)	(-)	(-)	(-)
53	Trichiniasis	Cases	277	395	367	393	327	353	487	451	(-)	(-)
54		Deaths	1	7	10	10	9	9	15	14	16	20
55	Tuberculosis, all forms	Cases	100,589	106,925	109,837	118,491	121,742	134,865	137,006	134,946	119,256	114,931
56		Deaths	16,392	19,544	24,621	30,863	33,959	39,100	43,833	48,064	50,911	52,916
57	Tularemia	Cases	681	601	668	702	927	1179	1086	1401	1355	900
58		Deaths	4	7	9	15	15	18	46	58	113	122
59	Typhoid fever	Cases	2169	2252	2341	2128	2484	2795	2840	3075	3268	4211
60		Deaths	45	52	78	83	96	161	205	282	349	471
61	Typhus fever, endemic (murine)	Cases	163	221	205	378	685	985	1171	2050	3365	5193
62		Deaths	0	0	0	0	0	2	68	88	128	173
	Venereal diseases[4]											
63	Gonorrhea	Cases	249,883	246,311	253,839	254,057	286,746	317,950	345,501	380,666	415,855	313,363
64		Deaths	15	29	45	43	37	66	71	108	150	212
65	Syphilis	Cases	131,260	150,026	169,198	174,924	217,558	256,463	314,313	355,592	385,524	351,767
66		Deaths	4835	5273	5719	6274	7568	8581	11,616	12,671	12,955	14,062
67	Other specified venereal	Cases	4650	5209	6093	6885	8187	11,034	12,559	14,371	13,461	10,261
68	diseases	Deaths	29	36	38	42	43	50	47	68	83	84
69	Whooping cough (pertussis)	Cases	60,886	37,129	45,030	68,687	120,718	69,479	74,715	156,517	109,860	133,792
70		Deaths	373	270	402	951	1118	727	1146	1954	1241	1752

/1/ For 1945-53, figures represent registered deaths. /2/ For 1945-51, figures from the Animal Disease and Parasite Research Branch, Agricultural Research Service, U. S. Department of Agriculture. /3/ None of these cases fulfill the criteria for a diagnosis of smallpox.
/4/ For 1945-51, figures (civilian cases only) from the Division of Venereal Diseases, U. S. Public Health Service.

Disease, Organism [Means of Dispersion]	Distances and Units Dispersed				
Plant Diseases					
1 Celery mosaic [insects]	Ft from harborer plant	3	28	120	225
	Diseased plants, %	100	52	16	0
2 Chestnut blight (Endothia parasitica) [air currents]	Ft from spore source	27	85	180	265
	Ascospores, no.	23	11	8	8
3 Citrus psorosis [unknown]	Tree spaces from source		1	2	3
	Diseased trees, %		32	20	14
4 Cucurbit mosaic, cucumber [insects]	Yd from harborer plant	1	225	350	500
	Days to 1st symptoms	17	45	47	49
5 Curley top, sugar beet [beet leafhopper]	Mi. from breeding ground		57	315	430
	Diseased plants, %		100	10	1
6 Dutch elm disease (Ceratostomella ulmi) [beetle]	Ft from inoculum source		12.5	300	575
	Diseased trees, no.		27	11	8
7 Downy mildew (Pseudoperonospora humilis) [air currents]	Ft from spore source	10	100	200	400
	Leaves infected, %	26	12	7	3
8 Onion mildew (Peronospora destructor) [air currents]	Ft from onion sets		120	780	2000
	Lesions/100 ft row, no.		1100	100	0
9 Potato calico [insects]	Rows from source		3	3	5
	Diseased plants, no.		26	22	13
10 Potato late blight (Phytophthora infestans)[air currents]	Ft from spore source	100	200	400	500
	Lesions/100 plants, no.	295	90	12	2
11 Potato leaf roll [aphids]	Rows from infected plants	1	2	4	6
	Diseased plants, %	21	12	5	1
12 Potato mosaic [insects]	Rows from diseased plants		1	3	6
	Diseased plants, %		36	18	6
13 Potato yellow dwarf (Macrosteles divisus) [insects]	Ft from old meadow	1	30	90	135
	Diseased plants, %	80	23	9	4
14 Rust, cedar, apple (Gymnospo-rangium sp) [air currents]	Yd from infected trees	0	55	220	440
	Leaf infections, no.	64	40	26	19
15 Rust, wheat stem (Puccinia graminis) [air currents]	Mi. from known source		200	740	940
	Spores collected, no.		13,000	8,000	7,000
16 Rust, white pine blister (Cronartium ribicola) [air currents]	Ft from gooseberry bush	50	250	450	650
	Diseased trees, %	75	46	36	29
17 Severe streak, raspberries [insects]	Rows from wild brambles	3	8	18	23
	Diseased plants, no.	165	85	21	1
18 Smut, loose, wheat (Ustilago tritici) [air currents]	Mi. from spore source	2	4	24	80
	Smutted heads, no.	240	235	115	0
Bacteria and Fungi (Miscellaneous)					
19 Bacterial colonies on sea water medium [air currents]	Mi. from land, over water		5	80	275
	Bacterial colonies, no.		41	58	65
20 Bacterial colonies on sea water medium [air currents]	Mi. from sea, over land		0	0.25	
	Bacterial colonies, no.		550	215	140
21 Spores (Bovista plumbea) [air currents]	Mi. from release point	5	10	15	20
	Spores caught, no.	910	325	165	100
22 Spores (Tilletia tritici) [air currents]	Mi. from release point	5	10	15	20
	Spores caught, no.	800	170	50	30
Plants (Seeds and Pollen)					
23 Bean, common (Phaseolus vulgaris) [air currents; insects(?)]	Yd from lima bean	1	2	3	5	9
	Cross pollination, %	9	7	6	4	3
24 Bean, lima (P. lunatus) [air currents; insects(?)]	Yd from common bean	1	2	3	5	9
	Cross pollination, %	5	4	3	2	1
25 Cedar, western red (Juniperus scopularum) [air currents]	Yd from seed source		22	44	66	88
	Seedlings per acre		615	175	55	9
26 Clover, alsike (Trifolium hybridum) [honey bees]	Yd from bee colonies			5.5	440	880
	Seeds per head, no.			38	33	32
27 Corn (Zea mays) [air currents]	Ft from contaminant			5.5	55.5	90
	Cross pollination, %			25	11	8
28 Fir, Douglas (Pseudotsuga taxifolia) [air currents]	Ft from seed trees		2	4	6	8
	Seedlings per acre		300	170	90	35

Disease, Organism [Means of Dispersion]	Distances and Units Dispersed				
Insects (concluded)					
59 Curculio, plum (Conotrachelus nenuphar) [flight]	Ft from release point		50	136	335	670
	Insects recovered, no.		48	13	2	1
60 Earworm, corn (Heliothis armigera) [flight] convergence	Rows from light traps		1	3	7	10
	Plants infested, %		32.4	31.9	31.6	31.3
61 Fly, apple maggot (Rhagoletis pomonella) [flight]	Ft from release point			37.5	137.5	237.5
	Flies recovered, no.			47	28	17
62 Fly, Hessian (Phytophaga destructor) [flight]	Ft from hibernation		7.5	27.5	47.5	97.5
	Plants infested, %		44	16	9	3
63 Fly, Hessian (P. destructor) [flight]	Ft from wheat field			100	400	600
	Flies caught, no.			95	16	12
64 Fly, house (Musca domestica) [flight]	Yd from release point			150	450	1050
	Flies caught, no. /trap/da			3.6	1.2	0.8
65 Fly, narcissus bulb (Merodon equestris) [flight]	Ft from old planting		7	85	200	300
	Plants infested, %		42	21	13	10
66 Fly, tsetse (Glossina morsitans) [flight]	Yd, following man		50	1000	4000	6000
	Flies, no.		30	13	5	3
67 Joint worm, wheat (Harmolita tritici) [flight]	Yd from wheat stubble		58	174	290	450
	Adults caught, no.		18	9	4	0
68 Leafhopper, beet (Circulifer tenellus) [flight]	Mi. from breeding area		15	35	105	215
	Leafhoppers caught, no.		500	150	15	4
69 Leafhopper, potato (Empoasca fabae) [flight]	Mi. from nearest land		3	6	9	10
	Leafhoppers caught, no.		38	27	21	20
70 Leafhopper, six-spotted (Macrosteles divisus) [flight, crawling]	Ft from release point			50	100	200
	Leafhoppers caught, no.			9	3	1
71 Leafhopper, six-spotted (M. divisus) [flight, crawling]	Ft. from release point			30	225	450
	Days to first recovery			4	13	16
72 Leafhopper, six-spotted (M. divisus) [flight]	Mi.from nearest land		3	6	9	10
	Leafhoppers caught, no.		515	145	37	18
73 Locust, migratory (Dissosteira longi-pennis and Melanoplus mexicanus) [flight]	Mi. from release point			25	125	225
	Locusts recovered, no.			8	6	5
74 Mosquito (Anopheles gambiae) [flight]	Mi. from release point		0.75	1.25	1.75	2.25
	Mosquitoes caught, no.		3.0	2.2	1.6	1.2
75 Mosquito (A. funestus) [flight]	Yd from release point		100	600	1200	2400
	Mosquitoes caught, no.		180	14	5	4
76 Mosquito (A. quadrimaculatus) [flight]	Mi. from breeding area		0.1	0.5	2.0	2.5
	Mosquitoes caught, no.		5000	1650	33	0
77 Mosquito (Anopheles spp), incidence of malarial infections	Ft from mosquito source		500	1500	3500	6000
	Infections, %		36	22	11	4
78 Mosquito, peat (Aedes and Culex spp) [flight]	Mi. from release point	1	4	8	12	16
	Mosquitoes caught, no.	97	37	17	6.3	0.3
79 Mosquito, rice field (Psorophora confinnis) [flight]	Mi. from release point	0.5	2.5	4.5	8.5	11.5
	Mosquitoes caught, no.	3.7	1.8	1.1	0.4	0
80 Mosquito, southern house (Culex quinquefasciatus) [flight]	Mi. from release point	0.8	1.4	2.0	2.6	3.1
	Mosquitoes caught, no.	2.8	2.0	1.4	1.0	0.7
81 Mosquito, yellow fever (Aedes and other spp) [flight], incidence of yellow fever	Mi. from original case			17.5	32.5	47.5
	Yellow fever cases, no.			14.6	4.6	1.7
82 Moth (Catocala spp) [flight]	Ft from release point		13	88	240	365
	Moths recovered, no.		8.1	3.7	1.5	0.6
83 Moth, codling (Carpocapsa pomo-nella) [flight]	Ft from release point		75	190	265	330
	Moths recovered, %		57	25	13	5
84 Moth, gypsy, males (Porthetria dispar) [flight]	Ft from moth source		330	660	1300	2600
	Moths recovered, no.		67	22	5	4
85 Moth, gypsy, larva (P. dispar) [carried by wind]	Ft from source	50	150	250	350	600
	Larvae, no.	16	4.4	1.7	1.3	0.5
86 Moth, oriental fruit (Grapholita molesta) [flight]	Ft from orchard			100	1300	2600
	Moths recovered, no.			194	14	8

29	Fir, silver (Abies alba)				55	165	275	87	Parasite, gypsy moth egg						100	900	3900	5100
	[air currents]				22	9	3		(Anastatus bifasciatus) [flight]						23	12	4	3
30	Hemlock, western (Tsuga hetero-			22	44	66	88								32	20	13	12
	phylla) [air currents]			1400	170	100	0	88	Parasite, Japanese beetle (Tiphia						7	49	77	90
31	Pine (Pinus spp). stand				3300	6200	8400		vernalis) [flight]						3.7	2.7	2.5	2.4
	[air currents]				2000	1000	500	89	Psyllid, blackberry (Trioza				1	3	5	10	20	25
32	Pine, western white (P. monticola)			22	44	66	88		tripunctata) [crawling]				10	5	4	3	1	0
	[air currents]			615	175	57	9	90	Screwworm, primary larva						In. from carcass		3	9	15	21
33	Pollen, apple (Malus pumila)				25	100	150		(Cochliomyia americana) [crawling]						320	47	4	2
	[honey-bees]				7	6	4	91	Screwworm, secondary (C. macel-						4.1	5.6	7.2	8.2
34	Pollen, cotton (Gossyptum hirsutum)			1	100	900	2000		laria) [flight]						37	22	10	4
	[wind or insects]			18	7	2	0	92	Strawworm, wheat (Harmolita						10	30	50	70
35	Pollen, radish (Raphanus sativus)			95	190	335	420		grandis) [crawling], spring form						4.2	2.1	0.9	0.1
	[wind or insects]		1	18	13	3	0	93	Strawworm, wheat (H. grandis)						1	50	100	150
36	Rye (Secale cereale)		75		0.3	5.3	10.6		[flight], summer form						52	19	13	10
	[air currents]				24	13	7	94	Weevil, cotton boll (Anthonomus							220	880	1760
37	Spruce, black (Picea marianna)				10	160	240		grandis) [flight]							59	26	9
	[air currents]				71,000	18,500	0	95	Weevil, cotton boll (A. grandis)						25	75	125	225
38	Tomato (Lycopersicon esculentum)			6	30	54	72		[crawling]						17	8	3	0
	[air currents; insects[?]]			1.1	0.4	0.1	0		Females recovered, no.						28	6	2	0
39	Walnut (Juglans regia)			60	500	1000	1600	96	Weevil, pea (Bruchus pisorum)							300	600	1400
	[air currents]			4	1.4	0.6	0		[flight]							51.	50	48
	Insects							97	Weevil, pea (B. pisorum) [flight]						2	3	4	5
40	Bee, honey (Apis mellifera)			5	16	27	33		Weevils, no.						13	8	5	3
	[flight]			6.1	2.6	0.9	0.3	98	Weevil, rice (Sitophilus oryzae)							For	100	200
41	Beetle, convergent ladybird (Hippo-			0.5	1.5	3.5	5.5		[crawling, probably]							3	2	1
	damia convergens) [flight]			1.1	0.6	0.3	0.1	99	Weevil, sugar cane, New Guinea							265	600	825
42	Beetle, elm bark, European (Scolytus				50	200	1000		(Rhabdocnemis obscura)							Beetles recovered, no.	26	8	1
	multistriatus) [flight]				39	14	3		[flight and crawling]							Days to recovery, no.	52	70	78
43	Beetle, elm bark, native (Hylurgo-		60	120	320	580	815									Vertical Dispersion			
	pinus rufipes) [flight]		14	9	5	2	1												
44	Beetle, flat grain (Laemophloeus			50	100	200	400	100	Bacteria, miscellaneous						Ft altitude		1,500	6,000	12,000	15,000
	minitum) [flight]			11	8	6	3		[air currents]						Bacteria, no.		113	48	15	5
45	Beetle, Japanese, larva (Popillia			22	42	62	84	101	Azalea flower spot (Ovulinia aza-						In. above ground		4	10	18	46
	japonica) [crawling]			79	44	23	7		lease)[air currents; water drip]						Infections, no.		42	28	17	0
46	Beetle, mountain pine (Dendroctonus			2	5	10	15	102	Onion mildew, spores (Peronospora						Ft altitude		100	200	700	1200
	monticolae) [flight]			63	26	10	1		destructor) [air currents]						Spores/cu ft air		32	100	450	600
47	Beetle, potato flea (Epitrix				100	300	500	103	Rust, wheat stem (Puccinia graminis)						Ft above barberry bushes			1,000	7,000	12,000
	cucumeris) [flight]				9	7	6		[air currents]						Aeciospores caught, no.			19	5	1
48	Beetle, red turpentine (Dendroctonus				50	200	400	104	Pollen, sugar beet (Beta vulgaris)						Ft altitude		1000	2000	3000	4000
	valens) [flight]				63	27	9		[air currents]						Grains caught, no.		56	26	14	9
49	Beetle, spotted cucumber (Diabrotica				11.5	105	273	105	Aphids[air currents and flight]						Mi. altitude		0.17	1.15	2.17	2.68
	duodecimpunctata) [flight]				0.32	0.22	0.17								Aphids caught, no.		2	9	16	19
50	Beetle, striped cucumber (D.			0.25	0.75	1.25	1.75	106	Beetle, ladybird (Coccinellids)						Mi., altitude		0.17	1.15	2.17	2.68
	vittia) [flight]			31	11	4	1		[flight]						Beetles caught, no.		40	13	4	1
51	Billbug, maize (Calandra maidis)			3	1	33	50	107	Beetle, tobacco flea (Epitrix						Ft altitude			12	19	23
	[crawling]			19	11	3	1		hirtipennis) [flight]						Beetles caught, no.			96	41	18
52	Black scale (Saissetia oleae)			13	200	250	450	108	Borer, European corn, moth						Ft altitude			5	10	15
	[air currents]			560	290	170	90		(Pyrausta nubilalis) [flight]						Moths caught, no.			915	545	330
53	Bollworm, pink (Pectinophora gossy-				1000	3500	6250	109	Fleshhopper, cotton (Psallus						Ft altitude		5.5	11.5	17.5	23.5
	piella) [flight]				1.33	1.20	1.16		seriatus) [flight; air currents]						Fleshhoppers caught, no.		61	97	156	250
54	Borer, roundheaded apple tree				Rows from release point			110	Fly, fruit [flight]						Mi. altitude		0.54	2.04	3.54	5.04
	(Saperda candida) [flight]			1	4	8	16								Flies caught, no.		415	235	165	115
55	Borer, European corn (Pyrausta nub-			103	47	39	39	111	Insects, miscellaneous						Ft altitude			10	177	277
	lialis) [flight] convergence		1	2	3	4	5		[flight; air currents]						Insects caught/cu ft air			239	51	21
56	Borer, European corn, larva (P.			85	62	51	41	36	112	Insects, miscellaneous						Ft altitude		20	1000	4000	7000
	nubialis) [crawling]			40	56	80	89	103		[flight; air currents]						Insects caught/10 min		26	6	3	1
57	Borer, strawberry crown (Tylo-			96	34	13	7	0												
	derma fragariae) [crawling]				25	68	125	300	113	Leafhopper, sugar beet (Circulifer						Ft altitude			8	16	25
58	Curculio, cowpea (Chalcodermus				6	5	4	1		tenellus) [flight]						Leafhoppers caught, no.			275	210	170
	aeneus) [unknown]					1.0	37.5	138	114	Mosquito, malarial (Anopheles						Ft altitude		1.5	3.0	6.0	7.5
						1.5	0.4	0.07		quadrimaculatus) [flight]						Mosquitoes caught, no.		14	11	5	3

Part I: PHYSICAL PROPERTIES AND CHEMICAL CONSTITUENTS

Values are per kg of water, unless otherwise indicated; values in parentheses are ranges.

	General Characteristics	Value
1	Density	1.02-1.03
2	Temperature	-1.5 to 30°C
3	pH, surface water	8.1-8.3
4	pH, at depth	7.5-8.1
5	Freezing point	-2°C[1]
6	Specific heat	0.93 Cal/g[2]
7	Velocity of sound	1450-1550 m/sec
8	Transparency, maximum[3]	66 m
9	Hydrostatic pressure[4]	1 atm/10 m
	Salinity[5]	g/kg
10	All oceans, average	35(33-37)
11	All oceans, below 1000 m (at -0.5 to 5°C)	34.6-35
12	Great depths (1-4°C)	34-35.2
13	At equator (average all oceans)	35
14	20th-40th parallel, N. Latitude	35.5
15	10th-30th parallel, S. Latitude	35.5
16	Average, 60°N. and S. Latitudes to the poles	35
17	North Pacific	34.5
18	North Sea, off Denmark	34
19	Indian Ocean, near Australia	35.5
20	South Pacific, off Peru	35.5
21	Arabian Sea	36-37
22	Sargasso Sea, N. Atlantic	36.5-37
23	South Atlantic, off Brazil	36-37
24	Red Sea (surface)	38-41
25	Mediterranean Sea (surface)	37-39
26	Gulf of Mexico (surface)	34-37
27	Antarctic Ocean (surface)	34-34.6
28	Arctic Ocean (surface)	32-33

Pressure-Depth Gradient[4]

	Depth	Salinity	Temp	Latitude 30°	Latitude 60°
	m	g/kg	°C	atm/m	atm/m
29	0	32	0	0.099141	0.099403
30	0	32	20	0.098831	0.099092
31	0	35	0	0.099138	0.099400
32	0	35	20	0.099052	0.099314
33	5000	35	0	0.101757	0.102026
34	5000	35	5	0.101660	0.101929
35	10,000	35	0	0.103952	0.104225

Oxygen Saturation Values from Normal Dry Atmosphere

	Chlorinity	15	16	17	18	19	20
36	Salinity	27.11	28.91	30.72	32.52	34.33	36.1
37	Temp °C	Oxygen ml/L[6]					
38	-2	9.01	8.89	8.76	8.64	8.52	8.39
39	0	8.55	8.43	8.32	8.20	8.08	7.97
40	5	7.56	7.46	7.36	7.26	7.16	7.07
41	10	6.77	6.69	6.60	6.52	6.44	6.35
42	15	6.14	6.07	6.00	5.93	5.86	5.79
43	20	5.63	5.56	5.50	5.44	5.38	5.31
44	25	5.17	5.12	5.06	5.00	4.95	4.86
45	30	4.74	4.68	4.63	4.58	4.52	4.46

	Average Surface Temperature, °C	Atlantic Ocean	Indian Ocean	Pacific Ocean
46	70-60 N	5.60		
47	60-50 N	8.66		5.74
48	50-40 N	13.16		9.99
49	40-30 N	20.40		18.62
50	30-20 N	24.16	26.14	23.38
51	20-10 N	25.81	27.23	26.42
52	10-0 N	26.66	27.88	27.20
53	70-60 S	-1.30	-1.50	-1.30
54	60-50 S	1.76	1.63	5.00
55	50-40 S	8.68	8.67	11.16
56	40-30 S	16.90	17.00	16.98
57	30-20 S	21.20	22.53	21.53
58	20-10 S	23.16	25.85	25.11
59	10-0 S	25.18	27.41	26.01

Relation of Chlorinity and Salinity to Specific Gravity

	Chlorinity[7] g/kg	Salinity[8] g/kg	Specific Gravity at 17.5°C
60	0	0.00	1.00000
61	1	1.84	1.00144
62	2	3.64	1.00283
63	3	5.45	1.00421
64	4	7.25	1.00558
65	5	9.06	1.00696
66	6	10.86	1.00834
67	7	12.67	1.00971
68	8	14.47	1.01109
69	9	16.28	1.01246
70	10	18.08	1.01383
71	11	19.89	1.01521
72	12	21.69	1.01658
73	13	23.50	1.01795
74	14	25.30	1.01933
75	15	27.11	1.02070
76	16	28.91	1.02208
77	17	30.72	1.02346
78	18	32.52	1.02484
79	19	34.33	1.02622
80	20	36.13	1.02760
81	21	37.94	1.02899
82	22	39.74	1.03037

Major Constituents[8]

	Substance	Value
	Anions	
83	Chloride	18.98 g
84	Sulfate	2.65 g
85	Bicarbonate	0.14 g
86	Bromide	65 mg
87	Fluoride	1.3 mg
88	Boric acid	26 mg

Major Constituents (concluded)

	Substance	Value
	Cations	
89	Sodium	10.56 g
90	Magnesium	1.27 g
91	Calcium	0.40 g
92	Potassium	0.38 g
93	Strontium	13 mg
	Element[8,9]	
94	Chlorine	18.98 g
95	Sodium	10.56 g
96	Magnesium	1.27 g
97	Sulfur	0.88 g
98	Calcium	0.40 g
99	Potassium	0.38 g
100	Bromine	65 mg
101	Carbon	28 mg
102	Strontium	13 mg
103	Boron	4.6 mg
104	Silicon	0.02-4.0 mg
105	Fluorine	1.4 mg
106	Nitrogen (comp.)	0.006-0.7 mg
107	Aluminum	70 μg
108	Rubidium	0.2 mg
109	Lithium	0.1 mg
110	Phosphorus	1-100 μg
111	Barium	54 μg
112	Iodine	54 μg
113	Arsenic	10-20 μg
114	Uranium	2-50 μg
115	Manganese	1-10 μg
116	Copper	1-10 μg
117	Zinc	5 μg
118	Lead	5 μg
119	Selenium	4 μg
120	Cesium	2 μg
121	Uranium	2 μg
122	Molybdenum	0.7 μg
123	Gallium	0.5 μg
124	Thorium	0.4 μg
125	Cerium	0.4 μg
126	Silver	0.3 μg
127	Vanadium	0.3 μg
128	Lanthanum	0.3 μg
129	Yttrium	0.3 μg
130	Bismuth	0.2 μg
131	Nickel	0.1 μg
132	Scandium	0.04 μg
133	Mercury	0.03 μg
134	Gold	0.004 μg
135	Radium	0.2-0.3 x 10^{-10} μg
136	Cadmium	Present
137	Chromium	Present
138	Cobalt	0.1 μg
139	Tin	3 μg

/1/ Value for water with salinity of slightly more 35 g/kg. /2/ Specific heat is a function of temperature, pressure and humidity; 0.93 approximates the value for sea water with a salinity of 34.85 g/kg at 20°C and atmospheric pressure (760 mm Hg). /3/ In Sargasso Sea, where a 30 cm Secchi disk disappears from sight at this depth. /4/ Hydrostatic pressure increases approximately 1 atmosphere (760 mm Hg) for each 10 m of depth, the exact value being affected by salinity, temperature and latitude. /5/ Total amount of solid material in g/kg of sea water when all carbonate has been converted to oxide, Br and I replaced by Cl, and all organic matter completely oxidized. /6/ mg-atoms of oxygen per liter = 0.08931 x ml/L; these values may be 3% too high). /7/ Chlorinity refers to total amount of Cl, Br and I in g/kg of sea water, and is equal to the mass, in grams, of "atomic weight silver" just necessary to precipitate the halogens in 0.3285233 kg. The standard chlorinity of sea water is 19, and equals salinity 34.325. /8/ Based on total salinity of 34.325. /9/ Nitrogen, oxygen, neon, helium and argon are also present as dissolved gases.

Part II: MARINE PLANT DISTRIBUTION

	Flora	Distribution
1	Seed plants (Spermatophyta)	None in deep oceans beyond continental shelves; 30 genera near coasts in 10-40 ft depths, all in 2 families (Hydrocharitaceae, Potamogetonaceae) as Halophila, Zostera, Thalassia, Phyllospadix.
2	Algae (Thallophyta)	Continental shelves all oceans with average salinity of 35, within 100 m depths; abundant near river mouths.
3	Blue-green (Myxophyceae)	Not abundant; nodularia in Norway fiords, Trichodesmum in Red Sea.
4	Green (Chlorophyceae)	Enteromorpha, Ulva in bays and harbors near surface; Codium, Halimeda (calcareous)[1] in tropics.
5	Brown (Phaeophyceae)	Ascophyllum, Fucus (smaller rock weeds); Laminaria, Nereocystis, Postelein (large kelps), attached to rocks in deeper water; Sargassum floating in Central Atlantic.
6	Red (Rodophyceae)	Small forms can live beyond continental shelves in depths of 30 m or more; Corallina of tropics is calcareous.[1]
7	Fungi and bacteria	In mud and oozes of ocean floors - no other plant life.
8	Plankton	On surface all oceans; diatoms, dinoflagellates, coccolithophores; microscopic, important food for sea animals.

/1/ Contributing to sand (lime) deposits.

M = million; B = billion.

Era (Duration, yr)	Major Division	Period (Years Ago)	Epoch	Duration yr	Advances in Life	Dominant Life
			Recent		Rise of civilization.	Age of man and herbaceous plants.
	Quaternary	(2 M)	Pleistocene	2 M	Periodic glaciation; extinction of great mammals and many trees; rise of modern herbs; elevation of continents.	
1 Cenozoic (60 M)	Tertiary	Late Tertiary	Pliocene	58 M	Continued cooling of climate; elevation of Andes; increasing restriction of plant distribution and forests; appearance of man.	
			Miocene		Climate changing greatly, becoming cool and semi-arid; elevation of Alps; restriction of distribution of plants; beginning of forest reduction; culmination of many mammals.	Age of modern life: mammals, birds, flowering plants.
			Oligocene		Climate warm, humid; elevation of Pyrenees; culmination of Eocene floras; world-wide distribution of tropical forests; primitive mammals disappear; rise of higher mammals and birds.	
		Early Tertiary	Eocene		Climate cool, semi-arid, then warm, humid; modernization of flowering plants; development of extensive forests, widespread in polar regions; modern birds and marine mammals appear.	
		(60 M)				
2 Mesozoic (125 M)		Cretaceous	Upper Cretaceous	65 M	Climate fluctuating; angiosperms dominant in floras, dicotyledons and monocotyledons of numerous existing genera well developed; disappearance of Bennettitales; rise of primitive mammals.	Age of reptiles and higher gymnosperms.
			Middle Cretaceous		Climate fluctuating; rapid development of angiosperms, appearance of many existing genera; specialization and extinction of great reptiles.	
			Lower Cretaceous		Climate very warm; rise of angiosperms(?); conifers and cycads still dominant; earliest known pines (Pinaceae).	
		(125 M)				
		Jurassic	Jurassic	32 M	Climate warm; beginning of Sierra Nevada Mountains; first certainly known angiosperms; conifers and cycads dominant; Ginkgoales and conifers world-wide; cordaites disappear; primitive birds and flying reptiles; rise of higher insects.	
		(157 M)				
		Triassic	Triassic	28 M	Climate warm, semi-arid;floras not luxuriant; gymnosperms increase, spread of conifers, rise of cycads and Bennettitales; seed ferns disappear; diversification of modern fern families well started; first mammals; rise of giant reptiles (dinosaurs).	
		(185 M)				
3 Paleozoic (368 M)	Late Paleozoic	Carboniferous	Permian	38 M	Climate dry; periodic glaciation, severe in southern hemisphere, elevation of Appalachians; dwindling of ancient groups, extinction of many; rise of ferns and conifers and land vertebrates; expansion of reptiles. Gondwana flora of southern hemisphere distinct from northern.	Age of amphibians, lycopods, and seed ferns.
		(223 M)				
			Pennsylvanian (271 M)	48 M	Dominant lycopods, seed ferns, horsetails; sphenophylls, Coniferales and calamites present; extensive coal formation.	
			Mississippian (309 M)	38 M	Dominant lycopods, horsetails, seed ferns; cordaites, sphenophylls, calamites present; rise of primitive reptiles and insects.	
	Middle Paleozoic	Devonian	Devonian	45 M	Early land floras: Psilophytales (Rhynie, Horneophyton); lycopods; primitive horsetails, including sphenophylls; primitive gymnosperms (earliest Cordaites and seed ferns, their seeds not yet known); first forests; rise of amphibians and fishes.	Age of fishes and early land plants.
		(354 M)				
		Silurian	Silurian	27 M	Algae dominant (e.g., Nematophyton heckii); first known land plants: Psilophytales and Lycopodiales, e.g., Baragwanathia; rise of lungfishes and scorpions (first air-breathing animals).	
		(381 M)				
	Early Paleozoic	Ordovician	Ordovician	67 M	Rise of corals, armored fishes (and land plants?); marine algae dominant; first known fresh-water fishes.	Age of higher invertebrates and algae.
		(448 M)				
		Cambrian	Cambrian	105 M	Climate warm, uniform over earth; first abundant fossils; many groups of marine invertebrates; dominant trilobites; marine plants, few algae determinable; Cambrian spores, pollen, tracheids in India, north-central Europe and Scandinavia.	
		(553 M)				
4 Proterozoic (900 M)		Precambrian (1.5 B)	Precambrian		Rocks chiefly sedimentary, of enormous thickness; glaciation; first fossils: worms, crustaceans, brachiopods; evidence of algal and bacterial life described.	Age of primitive marine invertebrates; fossils rare.
5 Archeozoic (550 M+)		(3.5-5 B)			Igneous rocks: lavas, metamorphosed rocks; few sedimentary; no direct evidence of life; graphites of possible organic origin in sedimentary rocks of Grenville age.	Age of unicellular life (?); fossils unknown.

Appendix

APPENDIX 1: TAXONOMIC CLASSIFICATION: ANIMALS

Classification adapted from A. S. Pearse's "Zoological Names," Section F, American Association for the Advancement of Science, Durham, North Carolina, 1948. Extinct groups are indicated by an asterisk (*).

KINGDOM: ANIMALIA
Subkingdom: Protozoa
I. PHYLUM: PROTOZOA
Subphylum: Plasmodroma
Class: Mastigophora
Subclass: Phytomastigina
Order: Chrysomonadina
Superfamily: Euchrysomonadina
Superfamily: Rhizochrysidina
Superfamily: Chrysocapsina
Order: Cryptomonadina
Superfamily: Eucryptomonadina
Superfamily: Phaecapsina
Order: Phytomonadina
Order: Euglenoidina
Order: Chloromonadina
Order: Dinoflagellata
Superfamily: Porocentrinea
Superfamily: Peridiniinea
Superfamily: Cystoflagellata
Subclass: Zoomastigina
Order: Rhizomastigina
Order: Protomonadina
Order: Polymastigina
Superfamily: Monomonadina
Superfamily: Diplomonadina
Superfamily: Polymonadina
Order: Hypermastigina
Class: Sarcodina
Subclass: Rhizopoda
Order: Proteomyxa
Order: Mycetozoa
Superfamily: Eumycetozoa
Superfamily: Sorophora
Order: Amoebina
Order: Testacea
Order: Foraminifera
Subclass: Actinopoda
Order: Heliozoa
Order: Radiolaria
Class: Sporozoa
Subclass: Telosporidia
Order: Gregarinida
Superfamily: Eugregarinaria
Superfamily: Schizogregarinaria
Order: Coccidia
Superfamily: Eimerides
Superfamily: Adelaides
Order: Haemosporidia
Subclass: Acnidosporidia
Order: Sarcosporidia
Order: Haplosporidia
Subclass: Cnidosporidia
Order: Myxosporidia
Superfamily: Eurysporea
Superfamily: Sphaerosporea
Superfamily: Platysporea
Order: Actinomyxidia
Order: Microsporidia
Superfamily: Monocnidea
Superfamily: Dicnidea
Order: Helicosporidia
Subphylum: Ciliophora
Class: Ciliata
Subclass: Protociliata
Subclass: Euciliata
Order: Holotricha
Superfamily: Astomata
Superfamily: Gymnostomata
Superfamily: Trichostomata
Superfamily: Hymenostomata
Superfamily: Thigmotricha
Superfamily: Apostomea
Order: Spirotricha
Superfamily: Heterotricha
Superfamily: Oligotricha
Superfamily: Ctenostomata
Superfamily: Hypotricha
Order: Chonotricha
Order: Peritricha
Superfamily: Sessilia
Superfamily: Mobilia
Class: Suctoria
Subkingdom: Mesozoa
Subkingdom: Parazoa
II. PHYLUM: PORIFERA
Class: Calcispongiae
Order: Asconosa
Order: Syconosa
Class: Hyalospongiae
Order: Hexasterophora
Order: Amphidiscophora
Class: Desmospongiae
Order: Carnosa
Order: Choristida
Order: Epipolasida
Order: Hadromerina
Order: Poecilosclerina
Order: Haplosclerina
Order: Keratosa
III. PHYLUM: *ARCHAEOCYATHA
Subkingdom: Metazoa
Subkingdom: Eumetazoa
IV. PHYLUM: COELENTERATA
Class: Hydrozoa
Order: Hydroida
Order: Trachylina
Order: Milleporina
Order: Stylasterina
Order: Siphonophora
Class: Scyphozoa
Order: Lucernariidea
Order: Charybdeidea
Order: Corona
Order: Semaeostomatae
Order: Rhizostomeae
Class: Anthozoa
Subclass: Octocorallia
Order: Stolonifera
Order: Telestacea
Order: Alcyonacea
Order: *Trachypsammiacea
Order: Coenothecalia
Order: Gorgonacea
Subclass: Scleraxonia
Subclass: Holaxonia
Order: Pennatulacea
Subclass: Sessiliflorae
Subclass: Subsessiliflorae
Subclass: Zoantharia
Order: Cerinthidea
Order: Antipatharia
Order: Zoanthidea
Order: Actiniaria
Suborder: Ptychodactiaria
Suborder: Corallimorpharia
Suborder: Actiniaria
Order: Scleractinia
Suborder: Astrocoeniida
Suborder: Fungiida
Suborder: Faviida
Suborder: Caryophylliida
Suborder: Dendrophylliida
Order: Rugosa
Order: Tabulata
V. PHYLUM: CTENOPHORA
Class: Tentaculata
Order: Cydippidea
Order: Lobata
Order: Cestoidea
Order: Platyctenea
Class: Nuda
Order: Beroidea
VI. PHYLUM: PLATYHELMINTHES
Class: Turbellaria
Order: Acoela
Order: Rhabdocoela
Suborder: Temnocephalida
Order: Alloiocoela
Order: Tricladida
Order: Polycladida
Class: Trematoda
Subclass: Monogenea
Order: Monopisthocotylea
Order: Polyopisthocotylea
Subclass: Aspidogastrea
Subclass: Digenea
Order: Gasterostoma
Order: Prosostomata
Class: Cestoidea
Subclass: Cestoidaria
Order: Amphilinidea
Order: Gyrocotylidea
Subclass: Cestoda
Order: Pseudophyllidea
Order: Cyclophyllidea
Order: Tetraphyllidea
Order: Trypanorhyncha
Order: Heterophyllidea
VII. PHYLUM: NEMERTEA
Class: Anopla
Order: Paleonemertea
Order: Heteronemertea
Class: Enopla
Order: Hoplonemertea
Suborder: Monostilifera
Suborder: Polystilifera
Order: Bdellonemertea
VIII. PHYLUM: ACANTHOCEPHALA
Class: Eoacanthocephala
Order: Gyracanthocephala
Order: Neoacanthocephala
Class: Metacanthocephala
Order: Palaeacanthocephala
Order: Archiacanthocephala
IX. PHYLUM: PROSOPYGIA
X. PHYLUM: ROTATORIA
Class: Seisonidea
Class: Bdelloidea
Class: Monogononta
Order: Ploima
Order: Flosculariacea
Order: Collothecacea
XI. PHYLUM: GASTROTRICHA
Order: Macrodasyoidea
Order: Chaetonotoidea
XII. PHYLUM: ECHINODERA
XIII. PHYLUM: NEMATOMORPHA
Class: Gordiidea
Class: Nectonematoidea
XIV. PHYLUM: NEMATOIDEA
Class: Phasmidia
Order: Rhabditida
Suborder: Rhabditata
Suborder: Ascaridata
Suborder: Strongylata
Order: Spirurida
Suborder: Spirurata
Suborder: Camallanata
Class: Aphasmidia
Order: Enoplata
Suborder: Enoplata
Suborder: Dorylaimata
Suborder: Dioctophymata
Order: Chromadorida
Suborder: Monohysterata
Suborder: Desmoscolecata
Suborder: Chromadorata
XV. PHYLUM: TARDIGRADA
Class: Heterotardigrada
Order: Arthrotardigrada
Order: Echiniscoidea
Class: Eutardigrada
XVI. PHYLUM: CHAETOGNATHA
XVII. PHYLUM: BRYOZOA
Class: Entoprocta
Class: Ectoprocta
Subclass: Gymnolaemata
Order: Cyclostomata
Suborder: Tubipora
Suborder: Ceriporina
Suborder: Ceramoporoidea
Suborder: Hederelloidea
Order: Trepostomata
Order: Cryptostomata
Order: Ctenostoma
Order: Cheilostomata
Suborder: Anasca
Suborder: Ascophora
Subclass: Phylactolaemata
XVIII. PHYLUM: BRACHIOPODA
Class: Inarticulata
Order: Atremata
Order: Neotremata
Class: Articulata
Order: *Paleotremata
Order: Protremata
Order: Telotremata
XIX. PHYLUM: PHORONIDEA
XX. PHYLUM: POEBIOIDEA
XXI. PHYLUM: POGONOPHORA

XXII. PHYLUM: *PTEROBRANCHIA
XXIII. PHYLUM: ENTEROPNEUSTA
Class: Balanoglossida
XXIV. PHYLUM: LINGUATULA
XXV. PHYLUM: ECHINODERMATA
Subphylum: Pelmatozoa
Class: *Cystoidea
Order: *Amphoridea
Order: *Rhombifera
Order: *Diploporita
Order: *Aporita
Order: *Edrioasteroida
Class: *Blastoidea
Order: *Protoblastoida
Order: *Eublastoida
Class: Crinoidea
Order: *Camerata
Order: *Adunata
Order: Flexibilia
Suborder: *Sagenocrinida
Suborder: *Taxocrinida
Order: *Inadunata
Suborder: *Larviformia
Suborder: *Fistulata
Order: Articulata
Suborder: Bourgueticrinida
Suborder: Pentacrinida
Suborder: Holopida
Order: Comatulida
Suborder: Oligophreata
Suborder: Macrophreata
Subphylum: Asterozoa
Class: Asteroidea
Order: Phanerozonea
Order: Spinulosa
Order: Forcipulata
Class: Ophiuroidea
Subclass: *Aegophiurida
Order: *Lysophiurida
Subclass: Myophiurida
Order: *Ophiocystiida
Order: *Aganasterida
Order: Phrynophiurida
Order: Laemophiurida
Order: Gnathophiurida
Order: Chilophiurida
Subphylum: Echinozoa
Class: Echinoidea
Order: *Bothriocidaroida
Order: Cidaroida
Order: Centrechinoida
Suborder: Auloclypeata
Suborder: Stirodonta
Suborder: Camerodonta
Order: Exocycloida
Suborder: Holectypina
Suborder: Echinoneina
Suborder: Clypeastrina
Suborder: Nucleolitina
Suborder: Cassidulina
Suborder: Urechinina
Suborder: Spatangina
Order: Perischoechinoida
Order: Echinocystoida
Order: Perichoechinoida
Class: Holothuroidea
Order: Dendrochirota
Order: Elasipoda
Order: Aspidochirota
Order: Molpadonia
Order: Apoda
XXVI. PHYLUM: PRIAPULOIDEA
XXVII. PHYLUM: ANNELIDA
Class: Archiannelida
Class: Polychaeta
Order: Errantia
Order: Sedentaria
Class: Myzostoma
Class: Oligochaeta
Order: Plesiopora plesiotheca
Order: Plesiopora prosotheca
Order: Prosopora
Order: Opisthopora
Class: Hirudinea
Order: Rhynchobdellida
Order: Gnathobdellida
Order: Pharyngobdellida
XXVIII. PHYLUM: ECHIUROIDEA
Class: Echiurida
Order: Echiuroinea
Order: Xenopneusta
Order: Heteromyota
Class: Saccosomatida
XXIX. PHYLUM: SIPUNCULOIDEA
XXX. PHYLUM: ONYCHOPHORA
XXXI. PHYLUM: ARTHROPODA
Subphylum: *Trilobita
Class: *Hypoparia
Class: *Opisthoparia
Class: *Proparia
Subphylum: Chelicerata
Class: Merostomata
Order: *Eurypterida
Order: *Synxiphosura
Order: Xiphosura
Class: Pycnogonida
Order: Colossendeomorpha
Order: Nymphonomorpha
Order: Ascorhynchomorpha
Order: Pycnogonomorpha
Class: Arachnida
Subclass: Latigastra
Order: Scorpiones
Order: Pseudoscorpiones
Order: Opiliones
Order: *Architarbi
Order: Acari
Suborder: Notostigmata
Suborder: Holothyroidea
Suborder: Parasitiformes
Suborder: Trombidiformes
Suborder: Sarcoptiformes
Suborder: Tetrapodili
Subclass: Stethostomata
Order: *Haptopoda
Order: *Anthracomarti
Subclass: Soluta
Order: Trigonotarbi
Subclass: Cuulogastra
Superorder: Latisterna
Order: Pelpigradi
Superorder: Camarostomata
Order: Schizomida
Order: Telyphonida
Order: Kustarachnae
Superorder: Labellata
Order: Phrynichida
Order: Araneae
Superorder: Cucullifera
Order: Ricinulei
Superorder: Nostrata
Order: Solifugae
Subphylum: Mandibulata
Superclass: Crustacea
Class: Eucrustacea
Subclass: Branchiopoda
Order: Anostraca
Order: Notostraca
Order: Conchostraca
Order: Cladocera
Suborder: Calyptomera
Suborder: Gymnomera
Subclass: Ostracoda
Order: Myodocopa
Order: Cladocopa
Order: Podocopa
Order: Platycopa
Subclass: Copepoda
Order: Eucopepoda
Suborder: Calanoida
Suborder: Harpacticoida
Suborder: Cyclopoida
Suborder: Notodelphyoida
Suborder: Monstrilloida
Suborder: Caligoida
Suborder: Lernaeopodoida
Order: Branchiura
Suborder: Arguloida
Subclass: Cirripedia
Order: Thoracica
Suborder: Turrilepadomorpha
Suborder: Lepadomorpha
Suborder: Verrucomorpha
Suborder: Balanomorpha
Order: Ascothoracica
Order: Apoda
Order: Rhizocephala
Subclass: Malacostraca
Infraclass: Leptostraca
Superorder: Phyllocarida
Order: Nebaliacea
Order: *Rhinocarina
Order: *Ceratiocarina
Order: *Hymenocarina
Superorder: *Nahecarida
Infraclass: Eumalacostraca
Superorder: Syncarida
Order: Anaspidacea
Superorder: Peracarida
Order: Mysidacea
Order: Thermosbaenacea
Order: Cumanea
Order: Tanaidacea
Order: Isopoda
Suborder: Flabellifera
Suborder: Valvifera
Suborder: Asellota
Suborder: Phreatoicidea
Suborder: Epicaridea
Suborder: Oniscoidea
Order: Amphipoda
Suborder: Gammaridea
Suborder: Hyperiidea
Suborder: Caprellidea
Suborder: Ingolfiellidea
Superorder: Eucarida
Order: Euphausiacea
Order: Decapoda
Suborder: Natantia
Suborder: Reptantia
Superorder: Hoplocarida
Order: Stomatopoda
Superclass: Pantopoda
Class: Pauropoda
Order: Pauropoda
Subclass: Ectomorpha
Subclass: Endomorpha
Class: Symphyla
Order: Symphyla
Class: Diplopoda
Subclass: Pselaphognatha
Order: Ancyrotricha
Order: *Lophotricha
Subclass: Chilognatha
Superorder: Opisthandria
Order: Limacomorpha
Order: Oniscomorpha
Suborder: Sphaerotheria
Suborder: Glomeridia
Superorder: Proterandria
Order: Colobognatha
Order: Nematophora
Suborder: Chordeumoidea
Suborder: Stemmiulioidea
Suborder: Strfaroidea
Suborder: Lysiopetaloidea
Order: Proterospermophora
Suborder: Polydesmoidea
Suborder: Strongylosomoidea
Order: Opisthospermophora
Suborder: Juloidea
Suborder: Spiroboloidea
Suborder: Spirostreptoidea
Suborder: Cambaloidea
Superclass: Opisthogoneata
Class: Chilopoda
Subclass: Pleurostigmophora
Superorder: Epimorpha
Order: Geophilomorpha
Order: Scolopendromorpha
Superorder: Anamorpha
Order: Lithobiomorpha
Order: Craterostigmorphora
Subclass: Notostigmorphora
Order: Scutigeromorpha
Class: Insecta
Subclass: Synaptera
Order: Collembola
Order: Protura
Order: Entotrophi
Order: Thysanura
Subclass: Pterygota
Order: Odonata
Order: Ephemeroptera
Order: Orthoptera
Order: Isoptera
Order: Dermaptera

Order: Plecoptera
Order: Embioptera
Order: Psocoptera
Order: Zoraptera
Order: Mallophaga
Order: Anoplura
Order: Hemiptera
Suborder: Heteroptera
Suborder: Homoptera
Order: Thysanoptera
Order: Neuroptera
Suborder: Megaloptera
Suborder: Raphidioidea
Suborder: Planipennia
Order: Mecoptera
Order: Diptera
Suborder: Nematocera
Suborder: Brachycera
Order: Siphonaptera
Order: Trichoptera
Order: Lepidoptera
Suborder: Jugatae
Suborder: Frenatae
Suborder: Rhopalocera
Order: Coleoptera
Suborder: Adephaga
Suborder: Polyphaga
Order: Hymenoptera
Suborder: Chalastogastra
Suborder: Clistogastra
Order: *Palaeodictyoptera
Order: *Megasecoptera
Order: *Protephemerida
Order: *Protodonata
Order: *Protoperlaria
Order: *Protelytroptera
Order: *Caloneurodea
Order: *Glosselytrodea
Order: *Protorthoptera
Order: *Protohemiptera

The following orders of insects are listed but have dubious recognition.

Order: *Protoblattoidea
Order: *Hadentomoidea
Order: *Syspharopteroidea
Order: *Miaxotermitoidea
Order: *Reculoidea
Order: *Haplaloperoidea
Order: *Protomecoptera
Order: *Paratrichoptera
Order: *Paramecoptera
Order: *Synarmogoidea
Order: *Diaphanopteroidea
Order: *Aeroplanoptera
Order: *Protohymenoptera
Order: *Protocoleoptera
Order: *Mixomoptera
Order: *Pruvostiioptera
Order: *Meganisoptera
Order: *Permodonata
Order: *Archodonata
Order: *Protodiptera
Order: *Hemipsocoptera
Order: *Cnemidolestodea
Order: *Paraplecioptera
Order: *Archaehymenoptera
Order: *Palaeohymenoptera
Order: *Protocicadida
Order: *Protofoligordia
Order: *Hemiodonata
Order: *Anisaxia
Order: *Perielytrodea
Order: *Permodictyoptera
Order: *Aphelophlebia

XXXII. PHYLUM: MOLLUSCA

Class: Creplpoda
Order: Eoplacophora
Order: Mesoplacophora
Order: Isoplacophora
Order: Teleoplacophora
Class: Gastropoda
Subclass: Prosobranchia
Order: Archaeogastropoda
Order: Mesogastropoda
Order: Neogastropoda
Subclass: Opisthobranchia
Order: Tectibranchia
Order: Pteropoda
Suborder: Thecosomata
Suborder: Gymnosomata
Order: Sacoglossa
Order: Acoela
Suborder: Notaspidea
Suborder: Nudibranchia
Subclass: Pulmonata
Order: Basommatophora
Order: Stylommatophora
Class: Scaphopoda
Class: Pelecypoda
Subclass: Prionodesmacea
Order: Palaeoconcha
Order: Taxodonta
Order: Schizodonta
Order: Dysodonta
Subclass: Anomalodesmacea
Order: Anomalobranchia
Order: Septibranchia
Subclass: Teleodesmacea
Order: *Pantodonta
Order: Diogenodonta
Order: Cycloconta
Order: Teleodonta
Order: Asthenodonta
Class: Cephalopoda
Order: Tetrabranchia
Suborder: Nautiloidea
Suborder: *Ammonitoidea
Order: Dibranchia
Suborder: Vampyromorpha
Suborder: Decapoda
Suborder: Octopoda

XXXIII. PHYLUM: CHORDATA

Subphylum: Tunicata
Class: Ascidiacea
Order: Stolidobranchiata
Order: Aspiraculata
Order: Phlebobranchiata
Order: Aplousobranchiata
Class: Larvacea
Class: Thaliacea
Subclass: Myosomata
Order: Salpida
Order: Doliolida
Subclass: Pyrosomata
Order: Pyrosomatida
Subphylum: Acrania
Class: Branchiostomi
Order: Branchiostomida
Subphylum: Craniata
Superclass: Agnatha
Class: *Cephalaspidomorphi
Order: *Osteostracida
Order: *Anaspida
Class: Petromyzontia
Order: Myxinida
Order: Petromyzontida
Class: *Pteraspidomorphi
Order: *Heterostracia
Order: *Coelolepida
Order: *Eupharerida
Superclass: Gnathostomata (Pisces)
Class: *Placodermi
Order: *Acanthodiida
Order: *Arthrodirida
Suborder: *Euarthrodrina
Suborder: *Arctolepina
Suborder: *Brachythoracina
Suborder: *Pyctolostina
Suborder: *Phyllolepina
Order: *Macropetalichthyida
Order: *Antiarchida
Order: *Stegoselachiida
Suborder: *Stensioellina
Suborder: *Rhenanina
Order: *Palaeospondylida
Class: Chondrichthyes
Subclass: *Xenacanthi
Order: *Xenacanthida
Subclass: *Cladoselachii
Order: *Cladoselachida
Subclass: Selachii
Superorder: Selachitica
Order: Hexanchida
Suborder: Hexanchina
Suborder: Chlamydoselachina
Order: Heterodontida
Suborder: *Hybodontina
Suborder: Heterodontina
Order: Galeida
Suborder: Galeina
Order: Squalida
Suborder: Squalina
Order: Squatinida
Suborder: Squatinina
Order: Pristiophorida
Superorder: Rajica
Order: Rajida
Suborder: Prostiina
Suborder: Gaidobatina
Suborder: Totpedinina
Suborder: Rajina
Suborder: Dasyatina
Subclass: Holocephali
Order: *Bradyodontida
Order: Chimaerida
Class: Osteichthyes
Subclass: Choanichthyes
Order: Neoceratodontida
Order: Crossopterygiida
Suborder: *Rhipidistiina
Suborder: Coelacanthina
Subclass: Actinopterygii
Superorder: Chondrosteica
Order: *Palaeoniscida
Order: Polypterida
Order: Acipenserida
Order: *Subholosteida
Superorder: Holosteica
Order: Lepisosteida
Order: *Pycnodontida
Order: *Aspidorhynchida
Order: Amiida
Order: *Pholidophorida
Superorder: Teleosteica
Order: Isopondylida
Suborder: Clupeina
Suborder: Salmonina
Suborder: Opisthoproctina
Suborder: Osteoglossina
Suborder: Stomiatina
Suborder: Gymnoblastodermina
Suborder: *Enchodontina
Suborder: Inlomina
Suborder: Berycomorphina
Suborder: Esocina
Order: Bathyclupeida
Order: Mormyrida
Order: Ateleopida
Order: Gigantmrida
Order: Lycenerida
Order: Ostariophysida
Suborder: Characina
Suborder: Gymnotina
Suborder: Cyprinina
Suborder: Silurina
Order: Anguillida
Order: Heteromida
Order: Synanchnida
Order: Synentognathida
Suborder: Scomberesocina
Suborder: Exocetina
Order: Cyprinodontida
Suborder: Amblyopsina
Suborder: Poeciliina
Order: Salmopercida
Order: Zeomorphida
Order: Solenichthyida
Order: Allotriognathida
Order: Anacanthida
Order: Gasterosteida
Order: Percomorphida
Suborder: Sphyraenina
Suborder: Phalloslethina
Suborder: Polynemina
Suborder: Anabantina
Suborder: Channina
Suborder: Percina
Suborder: Blennlina
Suborder: Ophidiina
Suborder: Ammodytina
Suborder: Schindlerlina
Suborder: Callionymina
Suborder: Trichiurina
Suborder: Scombrina
Suborder: Luvarina
Suborder: Tetragonurina
Suborder: Stromateina

Suborder: Kurtina
Suborder: *Rhamphosuna
Suborder: Gobiina
Order: Scorpaenida
Order: Cephalacanthida
Order: Pegasida
Order: Pleuronectida
Suborder: Psettodina
Suborder: Soleina
Order: Icosteida
Order: Chaudhuridae
Order: Mastocembelida
Order: Echeneida
Order: Tetraodontida
Suborder: Ballstina
Suborder: Ostracionina
Suborder: Tetraodontina
Suborder: Diodontina
Suborder: Molina
Order: Gobiesocida
Order: Batrachoidida
Order: Lophiida
Suborder: Lophiina
Suborder: Antennariina
Suborder: Ceratiina
Superclass: Tetrapoda
Class: Amphibia
Superorder: *Lasyrinthodontia
Order: *Ichthyostegalia
Order: *Rhachitomic
Suborder: *Loxommatoidea
Suborder: *Eobpoaidea
Suborder: *Eryopsoidea
Suborder: *Neorhachitomi
Order: *Stereospondyli
Order: *Embolomeri
Order: *Seymouriamorpha
Order: *Eoamura
Order: *Proanura
Order: Salientia
Suborder: Amphicoela
Suborder: Opisthocoela
Suborder: Anomocoela
Suborder: Procoela
Suborder: Diplasiocoela
Subclass: *Lepospondyli
Order: *Aistopoda
Order: *Nectridia
Order: *Microsauria
Order: Caudata
Suborder: Cryptobranchoidea
Suborder: Ambystomoidea
Suborder: Salamandrioidea
Suborder: Proteidea
Order: Apoda
Class: Reptilia
Subclass: Anapsida
Order: *Cotylosauria
Suborder: *Captorhinomorpha
Suborder: *Diadectomorpha
Order: Chelonia
Suborder: *Eunotosauria
Suborder: *Amphichelydia
Suborder: Athecae
Suborder: Thecophora
Subclass: *Ichthyopterygia
Subclass: *Synaptosauria
Order: *Protorosauria
Order: *Sauropterygia
Suborder: *Nothsauria
Suborder: *Pleiosauria
Suborder: *Placodontia
Subclass: Lepidosauria
Order: *Eosuchia
Suborder: *Tounginiformes
Suborder: *Choristodera
Suborder: *Thalattosauria
Suborder: *Acrosauria
Order: Rhynchocephalia
Order: Squamata
Suborder: Lacertilia
Suborder: Serpentes
Subclass: *Archosauria
Order: *Thecodontia
Suborder: *Pseudosuchia
Suborder: *Phytosauria
Order: Crocodilia
Suborder: *Protosuchia
Suborder: *Sebecosuchia
Suborder: *Mesosuchia
Suborder: Eusuchia

Order: *Pterosauri
Suborder: *Rhamphorhynchoidea
Suborder: *Pteradactyloidea
Order: *Saurischia
Suborder: *Theropoda
Suborder: *Sauropoda
Order: *Ornithischia
Suborder: *Ornithopoda
Suborder: *Ankylosauria
Suborder: *Ceratopsia
Subclass: *Synapsida
Order: *Pelycosauria
Suborder: *Ophiacodontia
Suborder: *Sphenacodontia
Suborder: *Edaphosauria
Order: *Therapsida
Suborder: *Dinocephalia
Suborder: *Dicynodontia
Suborder: *Theriodontia
Order: *Ictidosauria
Class: Aves
Subclass: *Archaeornithes
Order: Archaeopterygiformes
Subclass: Neornithes
Superorder: *Odontognathae
Order: *Hesperornithiformes
Order: *Ichthyornithiformes
Superorder: Palaeognathae
Order: Casuagnathiformes
Order: Struthioniformes
Order: Rheiformes
Order: Casuariiformes
Order: *Dinornithiformes
Order: *Aepyornithiformes
Order: Tinamiformes
Order: Impennes
Superorder: Neognathae
Order: Gaviiformes
Order: Colymbiformes
Suborder: Pterocletes
Suborder: Columbae
Order: Procellariiformes
Order: Sphenisciformes
Order: Pelecaniformes
Suborder: Phaethontes
Suborder: Pelecani
Suborder: Fregatae
Suborder: Odontopteryges
Order: Ciconiiformes
Suborder: Ardeinae
Suborder: Balaenicipites
Suborder: Ciconiae
Suborder: Phoenicopteri
Order: Anseriformes
Suborder: Anhimae
Suborder: Anseres
Order: Falconiformes
Suborder: Cathartae
Suborder: Falcones
Order: Galliformes
Suborder: Galli
Suborder: Opisthocomi
Order: Mesophagi
Order: Gruiformes
Suborder: Mesoenatides
Suborder: Turnices
Suborder: Grues
Suborder: Heliornithes
Suborder: Rhynochetі
Suborder: Eurypygae
Suborder: *Phororhaci
Suborder: Cariamae
Suborder: Otides
Order: *Distrymiformes
Order: Charadriiformes
Suborder: Charadrii
Suborder: Lari
Suborder: Alcae
Order: Psittaciformes
Order: Cuculiformes
Order: Strigiformes
Order: Caprimulgiformes
Suborder: Steatornithes
Suborder: Caprimulgi
Order: Apodiformes
Suborder: Micropodi
Suborder: Trochili
Order: Coliiformes
Order: Trogoniformes
Order: Coraciiformes
Suborder: Alcedines

Suborder: Meropes
Suborder: Coracii
Suborder: Bucorotes
Order: Piciformes
Suborder: Galbulae
Suborder: Pici
Order: Passeriformes
Suborder: Euryiaimi
Suborder: Tyranni
Suborder: Menurae
Suborder: Passeres
Class: Mammalia
Subclass: Prototheria
Order: Monotremata
Subclass: *Allotheria
Order: *Multituberculata
Order: *Tricnodonta
Subclass: Theria
Infraclass: *Pantotheria
Order: *Pantotheria
Order: Symmetrodonta
Infraclass: Metatheria
Order: Marsupialia
Infraclass: Eutheria
Cohort: Unguiculata
Order: Insectivora
Order: Dermoptera
Order: Chiroptera
Suborder: Megachiroptera
Suborder: Microchiroptera
Order: Primates
Suborder: Prosimii
Suborder: Anthropoidea
Order: *Tillodontia
Order: *Taeniodontia
Order: Edentata
Suborder: *Paleanodonta
Suborder: Xenarthra
Order: Pholidota
Cohort: Glires
Order: Lagomorpha
Order: Rodentia
Suborder: Sciuromorpha
Suborder: Myomorpha
Suborder: Hystricomorpha
Cohort: Mutica
Order: Cetacea
Suborder: *Archaeocetі
Suborder: Odontocetі
Suborder: Mysticeti
Cohort: Ferungulata
Superorder: Ferae
Order: Carnivora
Suborder: *Creodonta
Suborder: Fissipeda
Suborder: Pinnipedia
Superorder: *Protungulata
Order: *Condylarthra
Order: *Litopterna
Order: *Notoungulata
Suborder: *Notiopsygonia
Suborder: *Toxodonta
Suborder: *Typotheria
Suborder: *Hegetotheria
Order: *Astrapotheria
Suborder: *Trigonostylopoidea
Suborder: *Astrapotherioidea
Order: Tubulidentata
Superorder: Paramgulata
Order: *Pantodonta
Order: *Dinoceratа
Order: *Pyrotheria
Order: Proboscidia
Suborder: *Moeritherioidea
Suborder: Elephantoidea
Suborder: *Deinotherioidea
Suborder: *Barytherioidea
Order: *Embrithopoda
Order: Hyracoidea
Order: Sirenia
Suborder: Trichechiformes
Suborder: *Desmostyliformes
Superorder: Mesaxonia
Order: Perisodactyla
Suborder: Hippomorpha
Suborder: Ceratomorpha
Superorder: Paraxonia
Order: Artiodactyla
Suborder: Suiformes
Suborder: Tylopoda
Suborder: Ruminantia

APPENDIX II. TAXONOMIC CLASSIFICATION: PLANTS

Classification adapted from that of Engler, A., and Diels, L. Roman numerals refer to divisions.

Part I: PLANT KINGDOM: MAJOR GROUPS

I. SCHIZOPHYTA (Bacteria)
- Class: Schizomycetes
  - Order: Eubacteria
  - Order: Thiobacteria
- Class: Schizophycese

II. MYXOMYCETES (Slime molds)
- Order: Hydromyxales
- Order: Exosporales
- Order: Cribrariales
- Order: Enteridiales
- Order: Liceales
- Order: Stemonitales
- Order: Physarales
- Order: Margaritales
- Order: Trichiales

III. FLAGELLATAE (Flagellates)
- Order: Pantostomatales
- Order: Distomatales
- Order: Protomastigales
- Order: Chrysomonadales
- Order: Cryptomonadales
- Order: Chloromonadales
- Order: Euglenales

IV. DINOFLAGELLATAE
- Class: Adinifera
  - Order: Athecatales
  - Order: Thecatales
- Class: Dinifera
  - Order: Gymnodiniales
  - Order: Peridiniales

V. SILICOFLAGELLATAE
- Order: Siphonotestales
- Order: Stereotestales

VI. HETEROCONTAE

VII. BACILLARIOPHYTA (Diatoms)
- Class: Centricae
- Class: Pennales

VIII. CONJUGATAE (Green algae)

IX. CHLOROPHYCEAE (Blue-green algae)
- Class: Protococcales
  - Order: Volvocales
  - Order: Euprotococcales
- Class: Ulotrichales
- Class: Siphonocladales
- Class: Siphonales

X. CHAROPHYTA (Yellow-green algae)

XI. PHAEOPHYCEAE (Brown algae)
- Order: Ectocarpales
- Order: Sphacelariales
- Order: Cutleriales
- Order: Dictyotales
- Order: Laminariales
- Order: Tilopteridales
- Order: Fucales

XII. RHODOPHYCEAE (Red algae)
- Class: Bangiales
- Class: Florideae
  - Order: Nemalionales
  - Order: Gelidiales
  - Order: Cryptonemiales
  - Order: Gigartinales
  - Order: Rhodymeniales
  - Order: Ceramiales

XIII. EUMYCETES (Fungi)
- Class: Phycomycetes
  - Subclass: Oomycetes
    - Order: Monoblepharidales
    - Order: Saprolegniales
    - Order: Ancylistales
    - Order: Peronosporales
  - Subclass: Zygomycetes
    - Order: Mucorales
    - Order: Entomophthorales
  - Order: Endogonales
  - Order: Basidiobolales
- Class: Ascomycetes
  - Order: Spermophthorales
  - Order: Exoascales
  - Order: Laboulbeniales
- Class: Protomycetes
- Class: Basidiomycetes
  - Subclass: Hemibasidii
    - Order: Ustiaginales
    - Order: Uredinales
  - Subclass: Eubasidii
    - Order: Protobasidiomycetes
    - Order: Autobasidiomycetes

Supplement a[1]: Fungi imperfecti

Supplement b[1]: Lichenes
- Subclass: Phycolichenes
- Subclass: Ascolichenes
  - Order: Pyrenocarpeae
  - Order: Gymnocarpeae
- Subclass: Basidiolichenes

XIV. ARCHEGONIATAE

XIVa. BRYOPHYTA (Mosses, liverworts)
- Class: Hepaticae
  - Order: Marchantiales
  - Order: Anthocerotales
  - Order: Jungermanniales
- Class: Musci
- Subclass: Sphagnales
- Subclass: Andreaeales
- Subclass: Bryales
  - Order Group: Eubryinales
  - Order: Fissidentales
  - Order: Dicranales
  - Order: Pottiales
  - Order: Grimmiales
  - Order: Funariales
  - Order: Schistostegales
  - Order: Tetraphidiales
  - Order: Eubryales
  - Order: Isobryales
  - Order: Hookeriales
  - Order: Hypnobryales
  - Order Group: Buxbaumiinales
  - Order: Buxbaumiales
  - Order Group: Polytrichinales
  - Order: Polytrichales
  - Order: Dawsoniales

XIVb. PTERIDOPHYTA (Ferns and their allies)
- Class: Psilophytinae
- Class: Articulatae
  - Subclass: Protoarticulatales
  - Subclass: Sphenophyllales
  - Subclass: Cheirostrobales
  - Subclass: Pseudoborniales
  - Subclass: Equisetales
    - Order: Eusquisetales
    - Order: Calamitales
- Class: Lycopodiinae
  - Order: Lycopodiales
  - Order: Selaginellales
    - Suborder: Selaginellineae
    - Suborder: Lepidophytineae
- Class: Psilotinae
- Class: Isoetinae
- Class: Filicinae
  - Subclass: Eusporangiatae
    - Order: Ophioglossales
    - Order: Marattiales
  - Subclass: Leptosporangiatae
    - Order: Eufilicales
      - Suborder: Hydropteridales
      - Suborder: Gleicheniineae
      - Suborder: Schizaeineae
      - Suborder: Osmundineae
      - Suborder: Filicineae

XV. EMBRYOPHYTA SIPHONOGAMA (Phanerogamae)

XVa. GYMNOSPERMAE (Conifers and their allies)
- Class: Cycadofilicales
- Class: Cycadales
  - Family: Cycadaceae
- Class: Bennettitales
  - Family: Bennettitaceae
- Class: Ginkgoales
  - Family: Ginkgoaceae
- Class: Cordaitales
  - Family: Cordaitaceae
- Class: Coniferae
  - Family: Taxaceae
  - Family: Podocarpaceae
  - Family: Araucariaceae
  - Family: Cephalotaxaceae
  - Family: Pinaceae
  - Family: Taxodiaceae
  - Family: Cupressaceae
- Class: Gnetales
  - Family: Ephedraceae
  - Family: Welwitschiaceeae
  - Family: Gnetaceae

XVb. ANGIOSPERMAE (Flowering plants)
- Class: Monocotyledoneae
  - Order: Pandanales
  - Family: Typhaceae
  - Family: Pandanaceae
  - Family: Sparganiaceae
  - Order: Helobiae
    - Suborder: Potamogetoninеae
      - Family: Aponogetonaceae
      - Family: Potamogetonaceae
      - Family: Najadaceae
    - Suborder: Scheuchzeriineae
      - Family: Scheuchzeriaceae
    - Suborder: Alismatineae
      - Family: Alismataceae
    - Suborder: Butomineae
      - Family: Butomaceae
      - Family: Hydrocharitaceae
  - Order: Hydropteridales
- XV. EMBRYOPHYTA SIPHONOGAMA (Phanerogamae)

XVa. GYMNOSPERMAE (Conifers and their allies)
- Class: Cycadofilicales
- Class: Cycadales
- Class: Bennettitales
- Class: Ginkgoales
- Class: Cordaitales
- Class: Coniferae
- Class: Gnetales

XVb. ANGIOSPERMAE (Flowering plants)
- Class: Monocotyledoneae
  - Order: Pandanales
  - Order: Helobiae
  - Order: Triuridales
  - Order: Glumiflorae
  - Order: Principes
  - Order: Synanthae
  - Order: Spathiflorae
  - Order: Farinosae
  - Order: Liliiflorae
  - Order: Scitaminеae
  - Order: Microspermae
- Class: Dicotyledoneae
  - Subclass: Archichlamydeae
    - Order: Verticillatae
    - Order: Piperales
    - Order: Hydrostachyales
    - Order: Salicales
    - Order: Garryales
    - Order: Myricales
    - Order: Balanopsidales
    - Order: Leitneriales
    - Order: Juglandales
    - Order: Julianiales
    - Order: Batidales
    - Order: Fagales
    - Order: Urticales
    - Order: Podostemonales
    - Order: Proteales
    - Order: Santalales
    - Order: Aristolochiales
    - Order: Balanophorales
    - Order: Polygonales
    - Order: Centrospermae
    - Order: Ranales
    - Order: Rhoeadales
    - Order: Sarraceniales
    - Order: Rosales
    - Order: Pandales
    - Order: Geraniales
    - Order: Sapindales
    - Order: Rhamnales
    - Order: Malvales
    - Order: Parietales
    - Order: Opuntiales
    - Order: Myrtiflorae
    - Order: Umbelliflorae
  - Subclass: Metachlamydeae
    - Order: Diapensiales
    - Order: Ericales
    - Order: Primulales
    - Order: Plumbaginales
    - Order: Ebenales
    - Order: Contortae
    - Order: Tubiflorae
    - Order: Plantaginales
    - Order: Rubiales
    - Order: Cucurbitales
    - Order: Campanulatae

Part II: PHANEROGAMAE: FAMILIES

[1] Supplement to classes Ascomycetes and Protomycetes.

Part II: PHANEROGAMAE: FAMILIES (Continued)

Order: Triuridales
Family: Triuridaceae
Order: Ghumiflorae
Family: Gramineae
Family: Cyperaceae
Order: Principes
Family: Palmae
Order: Synanthae
Family: Cyclanthaceae
Order: Spathiflorae
Family: Araceae
Family: Lemnaceae
Order: Farinosae
Suborder: Flagellarinеae
Family: Flagellariaceae
Suborder: Enantioblastae
Family: Restionaceae
Family: Centrolepidaceae
Family: Mayacaceae
Family: Xyridaceae
Family: Eriocaulaceae
Suborder: Bromelinеae
Family: Thurniaceae
Family: Rapateaceae
Family: Bromeliaceae
Suborder: Commelinеae
Family: Commelinaceae
Suborder: Pontederinеae
Family: Pontederiaceae
Family: Cyanastraceae
Suborder: Philydrinеae
Family: Philydraceae
Order: Liliiflorae
Suborder: Juncinеae
Family: Juncaceae
Suborder: Liliinеae
Family: Stemonaceae
Family: Liliaceae
Family: Haemodoraceae
Family: Amaryllidaceae
Family: Velloziaceae
Family: Taccaceae
Family: Dioscoreaceae
Suborder: Iridinеae
Family: Iridaceae
Order: Scitaminae
Family: Musaceae
Family: Zingiberaceae
Family: Cannaceae
Family: Marantaceae
Order: Microspermae
Suborder: Burmanniinеae
Family: Burmanniaceae
Suborder: Gynandrae
Family: Orchidaceae
Class: Dicotyledoneae
Subclass: Archichlamydeae
Order: Verticillatae
Family: Casuarinaceae
Order: Piperales
Family: Saururaceae
Family: Piperaceae
Family: Chloranthaceae
Order: Hydrostachyales
Family: Hydrostachyaceae
Order: Salicales
Family: Salicaceae
Order: Garryales
Family: Garryaceae
Order: Myricales
Family: Myricaceae
Order: Balanopsidales
Family: Balanopsidaceae
Order: Leitneriales
Family: Leitneriaceae
Order: Juglandales
Family: Juglandaceae
Order: Julianiales
Family: Julianiaceae
Order: Batidales
Family: Batidaceae
Order: Fagales
Family: Betulaceae
Family: Fagaceae
Order: Urticales
Family: Ulmaceae
Family: Rhoipteleaceae
Family: Moraceae
Family: Urticaceae
Order: Podostemonales
Family: Podostemonaceae
Order: Proteales
Family: Proteaceae
Order: Santalales
Suborder: Santalinеae
Family: Olacaceae
Family: Opiliaceae
Family: Octoknemataceae
Family: Grubbiaceae
Family: Santalaceae
Family: Myzodendraceae
Suborder: Loranthinеae
Family: Loranthaceae
Order: Aristolochiales
Family: Aristolochiaceae
Family: Rafflesiaceae
Family: Hydnoraceae
Order: Balanophorales
Family: Balanophoraceae
Order: Polygonales
Family: Polygonaceae
Order: Centrospermae
Suborder: Chenopodinеae
Family: Chenopodiaceae
Family: Amaranthaceae
Suborder: Phytolaccinеae
Family: Nyctaginaceae
Family: Phytolaccaceae
Family: Gyrostemonaceae
Family: Achatocarpaceae
Family: Aizoaceae
Suborder: Portulacinеae
Family: Portulacaceae
Family: Basellaceae
Suborder: Caryophyllinеae
Family: Caryophyllaceae
Order: Ranales
Suborder: Nymphaeinеae
Family: Nymphaeaceae
Family: Ceratophyllaceae
Suborder: Trochodendrinеae
Family: Trochodendraceae
Family: Cercidiphyllaceae
Suborder: Ranunculinеae
Family: Ranunculaceae
Family: Lardizabalaceae
Family: Berberidaceae
Family: Menispermaceae
Suborder: Magnoliinеae
Family: Magnoliaceae
Family: Himantandraceae
Family: Calycanthaceae
Family: Lactoridaceae
Family: Anonaceae
Family: Eupomatiaceae
Family: Myristicaceae
Family: Gomortegaceae
Family: Monimiaceae
Family: Lauraceae
Family: Hernandiaceae
Order: Rhoeadales
Suborder: Rhoeadinеae
Family: Papaveraceae
Suborder: Capparidinеae
Family: Capparidaceae
Family: Cruciferae
Family: Tovariaceae
Suborder: Resedinеae
Family: Resedaceae
Suborder: Moringinеae
Family: Moringaceae
Suborder: Bretschneiderinеae
Family: Bretschneideraceae
Order: Sarraceniales
Family: Sarraceniaceae
Family: Nepenthaceae
Family: Droseraceae
Order: Rosales
Suborder: Saxifraginеae
Family: Crassulaceae
Family: Cephalotaceae
Family: Saxifragaceae
Family: Pittosporaceae
Family: Byblidaceae
Family: Brunelliaceae
Family: Cunoniaceae
Family: Myrothamnaceae
Family: Bruniaceae
Family: Hamamelidaceae
Family: Roridulaceae
Family: Eucommiaceae
Suborder: Rosinеae
Family: Platanaceae
Family: Crossosomataceae
Family: Rosaceae
Family: Connaraceae
Family: Leguminosae
Order: Pandales
Family: Pandaceae
Order: Geraniales
Suborder: Geraniinеae
Family: Oxalidaceae
Family: Geraniaceae
Family: Tropaeolaceae
Family: Linaceae
Family: Erythroxylaceae
Family: Zygophyllaceae
Family: Cneoraceae
Family: Rutaceae
Family: Simarubaceae
Family: Burseraceae
Family: Meliaceae
Family: Akaniaceae
Suborder: Malpighinеae
Family: Malpighiaceae
Family: Trigoniaceae
Family: Vochysiaceae
Suborder: Polygalinеae
Family: Polygalaceae
Suborder: Dichapetalinеae
Family: Dichapetalaceae
Suborder: Callitrichinеae
Family: Callitrichaceae
Order: Sapindales
Suborder: Buxinеae
Family: Buxaceae
Suborder: Empetrinеae
Family: Empetraceae
Suborder: Coriariinеae
Family: Coriariaceae
Suborder: Limnanthinеae
Family: Limnanthaceae
Suborder: Anacardiinеae
Family: Anacardiaceae
Suborder: Celastrinеae
Family: Cyrillaceae
Family: Pentaphylacaceae
Family: Corynocarpaceae
Family: Aquifoliaceae
Family: Celastraceae
Family: Hippocrateaceae
Family: Salvadoraceae
Family: Stackhousiaceae
Family: Staphyleaceae
Suborder: Icacinеae
Family: Icacinaceae
Suborder: Sapindinеae
Family: Aextoxicaceae
Family: Cneoraceae
Family: Hippocastanaceae
Family: Sabiaceae
Suborder: Sabiinеae
Family: Sabiaceae
Suborder: Melianthinеae
Family: Melianthaceae
Family: Didiereaceae
Family: Didiereaceae
Suborder: Balsaminеae
Family: Balsaminaceae
Order: Rhamnales
Family: Rhamnaceae
Family: Vitaceae
Order: Malvales
Suborder: Elaeocarpinеae
Family: Elaeocarpaceae
Suborder: Chlaenidеae
Family: Chlaenaceae
Suborder: Malvinеae
Family: Tiliaceae
Family: Malvaceae
Family: Bombacaceae
Family: Sterculiaceae
Suborder: Scytopetalinеae

APPENDIX II. TAXONOMIC CLASSIFICATION: PLANTS (Concluded)

Part II: PHANEROGAMAE: FAMILIES (Concluded)

Family: Scyopetalaceae
Order: Parietales
Suborder: Theineae
Family: Dilleniaceae
Family: Actinidiaceae
Family: Eucryphiaceae
Family: Medusagynaceae
Family: Ochnaceae
Family: Strasburgeriaceae
Family: Caryocarceae
Family: Marcgraviaceae
Family: Quiinaceae
Family: Theaceae
Family: Guttiferae
Family: Dipterocarpaceae
Suborder: Tamaricineae
Family: Elatinaceae
Family: Frankeniaceae
Family: Tamaricaceae
Suborder: Cistineae
Family: Cistaceae
Family: Bixaceae
Suborder: Cochlospermineae
Family: Cochlospermaceae
Suborder: Flacourtinieae
Family: Canellaceae
Family: Violaceae
Family: Flacourtiaceae
Family: Stachyuraceae
Family: Turneraceae
Family: Malesherbiaceae
Family: Passifloraceae
Family: Achariaceae
Suborder: Papayineae
Family: Caricaceae
Suborder: Loasineae
Family: Loasaceae
Suborder: Datiscineae
Family: Datiscaceae
Suborder: Begoniineae
Family: Begoniaceae
Suborder: Ancistrocladineae
Family: Ancistrocladaceae
Order: Opuntiales
Family: Cactaceae
Order: Myrtiflorae
Suborder: Thymelaeineae
Family: Geissolomataceae
Family: Penaeaceae
Family: Oliniaceae
Family: Thymelaeaceae
Family: Elaeagnaceae
Suborder: Myrtineae
Family: Lythraceae
Family: Heteropyxidaceae
Family: Sonneratiaceae
Family: Crypteroniaceae
Family: Punicaceae
Family: Lecythidaceae
Family: Rhizophoraceae
Family: Nyssaceae
Family: Alangiaceae
Family: Combretaceae
Family: Myrtaceae
Family: Melastomataceae
Family: Hydrocaryaceae
Family: Oenotheraceae
Family: Halorrhagaceae
Suborder: Hippuridineae
Family: Hippuridaceae
Family: Thelygonaceae
Suborder: Cynomoriineae
Family: Cynomoriaceae
Order: Umbelliflorae
Family: Araliaceae
Family: Umbelliferae
Family: Cornaceae
Subclass: Metschlamydeae
Order: Diapensiales
Family: Diapensiaceae
Order: Ericales
Subclass: Ericineae
Family: Clethraceae
Family: Pirolaceae
Family: Ericaceae
Subclass: Epacridineae
Family: Epacridaceae
Order: Primulales
Family: Theophrastaceae
Family: Myrsinaceae
Family: Primulaceae
Order: Plumbaginales
Family: Plumbaginaceae
Order: Ebenales
Suborder: Sapotineae
Family: Sapotaceae
Family: Hoplestigmataceae
Suborder: Diospyrineae
Family: Ebenaceae
Family: Diclidantheraceae
Family: Symplocaceae
Family: Styracaceae
Family: Lissocarpaceae
Order: Contortae
Suborder: Oleineae
Family: Oleaceae
Suborder: Gentianineae
Family: Desfontaineaceae
Family: Loganiaceae
Family: Gentianaceae
Family: Apocynaceae
Family: Asclepiadaceae
Order: Tubiflorae
Suborder: Convolvulineae
Family: Convolvulaceae
Family: Polemoniaceae
Family: Fouquieraceae
Suborder: Lennoineae
Family: Lennoaceae
Suborder: Borraginineae
Family: Hydrophyllaceae
Family: Borraginaceae
Suborder: Verbeninae
Family: Verbenaceae
Family: Labiatae
Suborder: Solaninae
Family: Nolanaceae
Family: Solanaceae
Family: Scrophulariaceae
Family: Bignoniaceae
Family: Pedaliaceae
Family: Martyniaceae
Family: Orobanchaceae
Family: Gesneriaceae
Family: Columelliaceae
Family: Lentibulariaceae
Family: Globulariaceae
Suborder: Acanthineae
Family: Acanthaceae
Suborder: Myoporineae
Family: Myoporaceae
Suborder: Phrymineae
Family: Phrymaceae
Order: Plantaginales
Family: Plantaginaceae
Order: Rubiales
Family: Rubiaceae
Family: Caprifoliaceae
Family: Adoxaceae
Family: Valerianaceae
Family: Dipsacaceae
Order: Cucurbitales
Family: Cucurbitaceae
Order: Campanulatae
Family: Campanulaceae
Family: Goodeniaceae
Family: Brunoniaceae
Family: Stylidiaceae
Family: Calyceraceae
Family: Compositae

APPENDIX III: ESTIMATED NUMBER OF SPECIES: ANIMAL, PLANT KINGDOM

	Group	Number of Species[1]
	Animal Kingdom	
1	Protozoa	15,000
2	Porifera	5,000
3	Coelenterata	10,000
4	Ctenophora	100
5	Platyhelminthes	6,000
6	Nemertea	500
7	Nemathelminthes	5,000
8	Trochelminthes	2,000
9	Bryozoa	3,000
10	Brachiopoda	120
11	Phoronides	15
12	Chaetognatha	30
13	Annelida	6,500
14	Arthropoda	750,000
15	Crustacea	25,000
16	Arachnoidea	15,000
17	Onychophora	80
18	Myripoda	7,000
19	Insecta	700,000[2]
20	Molluscа	70,000[3]
21	Echinodermata	5,000
22	Crinoidea	635
23	Asteroides	1,500
24	Ophiuroides	1,500
25	Echinoides	771
26	Holothurioidea	600
27	Chordata	60,000
28	Tunicata	700
29	Leptocarida	30
	Vertiebrata	
30	Pisces	40,000[4]
31	Amphibia	2,769[5]
32	Reptilia	6,959[5]
33	Aves	8,600[6]
34	Mammalia	3,000-5,000[7]
35	Total	938,000[8]
	Plant Kingdom	
36	Thallophyta	106,965
37	Chlorophyta	5,700
38	Euglenophyta	335
39	Pyrrophyta[9]	1,000
40	Chrysophyta[10]	5,700
41	Phaeophyta	900
42	Cyanophyta	1,400
43	Rhodophyta	2,500
44	Myxomycetes	430
45	Eumycophyta	73,500
	Phycomycetes	1,500
47	Ascomycetes	25,000
48	Basidiomycetes	23,000
	Eumycophyta (concluded)	
49	Deuteromycetes	24,000
50	Lichenes	15,500
51	Bryophita	23,820
52	Hepaticae	8,500
53	Anthocerotae	320
54	Musci	15,000
55	Pteridophyta	11,280
56	Psilotales	3
57	Lycopodiales	483
58	Selaginellales	700
59	Isõetales	64
60	Equisetales	32
61	Filicales	10,000
62	Spermatophyta	200,665
63	Gymnospermae	665
64	Cycadales	100
65	Ginkgoales	1
66	Coniferae	520
67	Gnetalea	44
68	Angiospermae	200,000
69	Monocotyledones	34,000
70	Dicotyledonea	166,000
71	Total	342,730

/1/ Exclusive of lower classification (subspecies, etc.), unless otherwise indicated. /2/ Estimated number of forms (species, subspecies, etc.), 900,000. /3/ Estimated number of forms, 100,000. /4/ Value includes "fish-like" vertebrates (Cyclostomata and Elasmobranchii). /5/ Applicable to number of forms. /6/ Estimated number of forms, 32,000. /7/ Estimated number of forms 20,000. /8/ Incomplete, recent estimates not available. /9/ Including Cryptophyceae, Desmokontae and Dinophyceae. /10/ Including Heterokontae and Chrysophyceae.

APPENDIX IV: SYMBOLS, UNITS, CONSTANTS, AND CONVERSION FACTORS

Although many of the values and symbols listed here may not be used as such in the handbook, they will help the user translate values into units more applicable to his field, or to make a physical-chemical-biological correlation of data. Some of the tables include definitions and conversion factors which may not be listed here. In several instances two or more units of measurement may have the same symbol (e.g., M = mole; M= million); however, the possibility of confusion is remote because of the difference in the subject material where the units are applicable. The singular and plural forms of abbreviations are the same.

ABBREVIATIONS AND SYMBOLS USED IN THE HANDBOOK

mi = mile
yd = yard
ft = foot
in. = inch
km = kilometer
hm = hectometer
m = meter
dm = decimeter
cm = centimeter
mm = millimeter
μ = micron (10^{-6}mm)
c_{mm} = millimicron (10^{-9}mm)
Å = angstrom unit
$\mu\mu$ = millionth micron (10^{-9}mm)
sq = square (e.g., sq m = square meter)
cu = cubic (e.g., cu cm = cubic centimeter)

lb = pound
oz = ounce
kg = kilogram
g = gram
dg = decigram
cg = centigram
mg = milligram
μg = microgram
gal = gallon
qt = quart
pt = pint
kl = kiloliter
hl = hectoliter
L = liter
ml = milliliter
μl = microliter

yr = year
mo = month
wk = week
da = day
hr = hour
min = minute
sec = second
msec = millisecond
Cal = Calorie (kilocalorie)
cal = calorie (gram calorie)
°F = degrees Fahrenheit
°C = degrees centigrade
M = mole
F = farad
r = roentgen
c = curie

ev = electron volt
sp gr = specific gravity
BP = boiling point
MP = melting point
$[\alpha]_D$ = optical rotation
MW = molecular weight
σ = male
φ = female
mEq = milliequivalent
atm = atmosphere
μ = micro- (10^{-6})
m = milli- (10^{-3})
c = centi- (10^{-2})
k = kilo- (10^{3})
M = mega- (10^{6})
B = billion (10^{9})

SYSTEMS OF UNITS

In many tables units are indicated in relationship to other measurements, as, for example, calories per square centimeter per hour. As an expedient to conserve space, these are presented as cal/sq cm/hr. The slashes in such cases should always be interpreted as "per" rather than as fractional designations.

A. Mechanical

System	Length	Mass	Time	Force	Velocity	Acceleration	Torque	Pressure	Energy	Power	Momentum
Meter-Kilogram-Second	Meter (m)	Kilogram (kg)	Second (sec)	Newton (nt)	m/sec	m/sec^2	m-nt	nt/m^2	Joule	Watt	kg-m/sec
Centimeter-Gram-Second	Centimeter (cm)	Gram (g)	sec	Dyne	cm/sec	cm/sec^2	dyne-cm	$dyne/cm^2$	Erg	Erg/sec	g-cm/sec
Foot-Pound-Second	Foot (ft)	Pound (lb)	sec	Poundal (pd)	ft/sec	ft/sec^2	pdl-ft	pdl/ft	ft-pdl	ft-pdl/sec	ft-lb/sec

B. Electrical

System	Energy	Power	Current	Charge	Electric Potential	Resistance	Electric Intensity	Capacitance	Inductance
Meter-Kilogram-Second	Joule	Watt (Joule/sec)	Ampere	Coulomb	Volt	Ohm	Volt/meter	Farad	Henry
Electromagnetic	Erg	Erg/sec	Abampere	Abcoulomb	Abvolt	Abohm	Abvolt/cm	Abfarad	Abhenry
Electrostatic	Erg	Erg/sec	Statampere	Statcoulomb	Statvolt	Statohm	Statvolt/cm	Statfarad	Stathenry

SOME USEFUL CONSTANTS

Constant	Value	Reciprocal	Logarithm
$1/4\pi$	0,7853981634	1.2732395447	1.8950898814
$1/2\pi$	1.5707963268	0.6366197724	0.1961198770
π	3.1415926536	0.3183098862	0.4971498727
2π	6.2831853072	0.1591549431	0.7981798684
$\sqrt{\pi}$	1.7724538509	0.5641895835	0.2485749363
$\sqrt{2\pi}$	2.5066282746	0.3989422804	0.3990899342
$\sqrt{1/2\pi}$	1.2533141373	0.7978845608	0.0980599385
$1/2\sqrt{\pi}$	0.8862269255	1.1283791671	1.9475449407
e	2.7182818285	0.3678794412	0.4342944819
e^2	7.3890560989	0.1353352832	0.8685889638
$\sqrt{e}$	1.4142135624	0.7071067812	0.1505149978
$\sqrt{3}$	1.7320508076	0.5773502692	0.2385606274
$\sqrt{10}$	3.1622776602	0.3162277660	0.5000000000
$\log_{10}e$	0.4342944819	2.3025850930	1.6377843113
Radian	57.2957795131°	0.0174532925	1.7581226324

Binomial Coefficients

	Value of n_2									
4	5	6	7	8	9	10	11	12	1
1	1	1	1	1	1	1	1	1	0
4	5	6	7	8	9	10	11	12	1
6	10	15	21	28	36	45	55	66	2
4	10	20	35	56	84	120	165	220	3
1	5	15	35	70	126	210	330	495	4
	1	6	21	56	126	252	462	792	5
		1	7	28	84	210	462	924	6
			1	8	36	120	330	792	7
				1	9	45	165	495	8
					1	10	55	220	9
						1	11	66	10
							1	12	11
								1	12

Speed of light in a vacuum; also, ratio of emu to esu of electric charge (c)	$(2.99776\pm0.00004) \times 10^{8}$ m/sec
Charge of an electron (e)	$(1.6020\pm0.0002) \times 10^{-19}$ coulomb
Faraday's constant; the charge transported by a gram atom of a univalent element (F)	(96,522±7) coulombs/mole
Avogadro's number; the number of molecules in a gram molecule or of atoms in a gram atom (N_0)	$(6.0251\pm0.0004) \times 10^{23}$
Standard atmospheric pressure (P_0)	(101,324.6±0.4) nt/sq m
Freezing point of water on the absolute (Kelvin) scale (T_0)	(273.16±0.02) °K
Density of mercury at STP	(13,595.04±0.06) kg/cu m
Atomic weight of oxygen, physical scale*	(16.00436±0.00009)
Volume of a mole of perfect gas at STP (V_0)	(22,420.7±0.6) cu cm
Universal gas constant (R_0)	(8,316.6±0.4) joules/kg-°K
Boltzmann's constant; gas constant per molecule (k)	$(1.3803\pm0.0001) \times 10^{-23}$ joule/°K
Mass of atom of unit atomic weight, physical scale* (m_1)	$(1.6589\pm0.0014) \times 10^{-24}$ g
Mass of electron (m_e)	$(9.103\pm0.008) \times 10^{-28}$ g
Mechanical equivalent of heat	(4185.5±0.4) joules/Cal
Gravitation constant (G)	$(6.670\pm0.005) \times 10^{-11}$ nt-sq m/sq kg
Planck's (quantum) constant (h)	$(6.623\pm0.001) \times 10^{-34}$ joule-sec

*An atomic weight of 16 for oxygen (as determined by chemical analysis) is the basis for the chemical scale of atomic weights. In the physical scale the value of 16 is assigned to the most abundant isotope of oxygen. Physical scale atomic weights are larger than those in the chemical scale by a ratio of 1.00027 to 1.

CONVERSION FACTORS

Units expressed in Column A, when multiplied by the accompanying factor in Column B, are converted to units expressed in Column C.

Column A	x	Column B	=	Column C
Abamperes		10.0000		amperes
Abamperes		2.99796 x 10^{10}		statampere
Abcoulombs		10.0000		coulombs (Abs.)
Abcoulombs		2.99796 x 10^{10}		statcoulombs
Abcoulombs/kg		30577		statcoulombs/dyne
Abcoulombs/lb		6.7411 x 10^{4}		statcoulombs/dyne
Abfarads		1.0000 x 10^{9}		farads (Abs.)
Abfarads		1 x 10^{15}		microfarads
Abfarads		8.98776 x 10^{20}		statfarads
Abhenries		1.0000 x 10^{-9}		henries (Abs.)
Abhenries		1 x 10^{-6}		millihenries
Abhenries		1.11263 x 10^{-21}		stathenries
Abmhos/cu cm		1000		megmhos/cu cm
Abmhos/cu cm		1.00052 x 10^{9}		mhos,International/cu cm
Aimhos/cu cm		166.2		mhos/mil ft
Abohms		1 x 10^{-15}		megohms
Abohms		0.001		microhms
Abohms		1.0000 x 10^{-9}		ohms (Abs.)
Abohms		1.11263 x 10^{-21}		statohms
Abvolts		0.010000		microvolts
Abvolts		3.33560 x 10^{-1}		statvolts
Abvolts		1.0000 x 10^{-8}		volts (Abs.)
Abvolts/cm		1.0000 x 10^{-8}		volts (Abs.)/cm
Abvolts/^{o}F		0.018000		microvolts/^{o}C
Abvolts/in.		3.9370 x 10^{-9}		volts (Abs.)/cm
Acres (U. S.)		40.46873		ares (sq. dekameters)
Acres (U. S.)		0.4046873		hectares (sq. hectometers)
Acres (U. S.)		43560		sq ft
Acres (U. S.)		4046.873		sq m
Acres (U. S.)		0.0015625		sq mi
Acres (U. S.)		160		sq rods
Acres (U. S.)		4840		sq yd
Amperes (Abs.)		0.1		abamperes
Amperes (Abs.)		1.00007		amperes (International)
Amperes (Abs.)		1.0363 x 10^{-5}		faradays/sec
Amperes (Abs.)		2.99796 x 10^{9}		statamperes
Ampere-hr (Abs.)		3600.0		coulombs (Abs.)
Angstrom units		3.937 x 10^{-9}		inches
Angstrom units		1 x 10^{-10}		meters
Angstrom units		100		micro-microns
Angstrom units		1 x 10^{-4}		microns
Angstrom units		0.1		milli-microns
Atmospheres		1.0133		bars
Atmospheres		76		cm Hg at 0°C
Atmospheres		1.01325 x 10^{6}		dynes/cm^{2}
Atmospheres		33.899		ft of water at 39.1^{o}F
Atmospheres		1033.3		g/sq cm
Atmospheres		29.921		in. Hg at 32°F
Atmospheres		10333		kg/sq m
Atmospheres		760000		microns of Hg
Atmospheres		760		mm Hg
Atmospheres		2116.32		lb/sq ft
Atmospheres		14.696		lb/sq in.
Barrels (U.S., dry)		3.281		bushels
Barrels (U.S., dry)		7056		cu in.
Barrels (U.S., dry)		0.11562		cu m
Barrels (U.S., dry)		105.0		quarts (dry)
Barrels (U.S., liquid)		0.11924		cu m
Barrels (U.S., liquid)		31.5		gallons
BTU		252		gram calories
BTU		25030		foot poundals
BTU		777.9		ft lb
BTU		3.929 x 10^{-4}		horse power hr
BTU		1055		joules
Bushels (U.S., dry)		0.304785		barrels
Bushels (U.S., dry)		35239		cu cm
Bushels (U.S., dry)		1.2444		cu ft
Bushels (U.S., dry)		2150.42		cu in.
Bushels (U.S., dry)		0.035239		cu m
Bushels (U.S., dry)		35.23839		hectoliters
Bushels (U.S., dry)		35.238329		liters
Bushels (U.S., dry)		4		pecks
Bushels (U.S., dry)/acre		0.870754		hectoliters/hectare
Calories, g		3.968 x 10^{-3}		BTU
Calories, g (mean)		0.001469		cu ft atm
Calories, g (mean)		99.334		foot-poundals
Calories, g (mean)		3.0874		ft lb
Calories, g		1.5591 x 10^{-6}		horse power hr
Calories, g (15°C)		4.185		joules (Abs.)
Calories, g (mean)		0.42685		kg m
Calories, g (mean)		4.1311 x 10^{-2}		L-atm
Calories, g (mean)		0.0011628		watt hr
Calories (15°C) sec		6.3854 x 10^{33}		quanta
Calories (15°C)/am-pere-hr		0.011625		joules/abcoulomb
Calories (15°C)/coulomb		41.850		joules/abcoulomb
Calories, gram (15°C)/^{o}C		0.0022046		BTU (60°F)/^{o}F
Calories, gram (15°C)/^{o}C		4.185		joules/^{o}C
Calories, gram (mean)/g		1.8		BTU (mean)/lb
Calories, gram (mean)/g/^{o}C		1		BTU (60°F)/lb/^{o}F
Calories, gram (mean)/g/^{o}C		4.186		joules/g/^{o}C
Calorie (15°C) sec/N_o *		1.0535 x 10^{10}		quanta
Calories, kg (mean)		3.9685		BTU (mean)
Calories, kg (mean)		1000		gram calories, (mean)
Calories, kg (mean)		4.186 x 10^{10}		ergs
Calories, kg (mean)		3087.4		ft lb
Calories, kg (mean)		4.2686 x 10^{7}		g cm
Calories, kg (mean)		0.0015593		horse power hr
Calories, kg (mean)		4186		joules
Calories, kg (mean)		426.85		kg m
Calories, kg (mean)		0.0011628		KW hr
Calories, kg (mean)/min		51.457		lb/sec
Calories, kg (mean)/min		0.093558		horse power
Calories, kg (mean)/min		69.769		watts
Calories, kg (mean)/sec		4.186		kilowatts
Candles (International)		1.0000		lumens (International)/steradian
Candle power (spherical)		12.566		lumens
Candles/sq cm		3.1416		lamberts
Candles/sq in.		0.48695		lamberts
Centigrade thermal unit (15°C)		1898.3		joules (Abs.)
Centimeters		1 x 10^{8}		angstrom units
Centimeters		0.032808		feet (British or U.S.)
Centimeters		0.393700		inches (U.S.)
Centimeters		10000		microns
Centimeters		393.70		mils
Centimeters		0.0109361		yards (U. S.)
Cm Hg at 0°C		0.013158		atmospheres
Cm Hg at 0°C		1.33322 x 10^{4}		dynes/sq cm
Cm Hg at 0°C		0.44604		ft of water at 39.1^{o}F
Cm Hg at 0°C		135.95		kg/sq m
Cm Hg at 0°C		27.845		lb/sq ft
Cm Hg at 0°C		0.19337		lb/sq in.
Centimeters/sec		1.9685		ft/min
Centimeters/sec		0.03600		km/hr
Centimeters/sec		0.6000		m/min
Centimeters/sec		0.02237		mi/hr
Centimeters/sec		3.728 x 10^{-4}		mi/min
Centimeters/sec^{2}		0.036		km/hr/sec
Centimeters/sec^{2}		0.02237		mi/hr/sec
Circles		360		degrees
Circles		6.28319		radians
Circular in.		5.0671		sq cm
Circular in.		0.78540		sq in.
Circular mm		0.78540		sq mm
Circumferences		360		degrees
Circumferences		400		grades
Coulombs (Abs.)		0.1000		abcoulombs or electromagnetic cgs units
Coulombs (Abs.)		1.00010		coulombs (International)
Coulombs (Abs.)		6.281 x 10^{18}		electronic charges
Coulombs (Abs.)		2.99796 x 10^{9}		electrostatic cgs units or statcoulombs
Coulombs (International)		0.99990		coulombs (Abs.)
Coulombs/kg		3057.7		statcoulombs/dyne
Cubic cm		3.531445 x 10^{-5}		cu ft (U. S.)
Cubic cm		0.061023		cu in.
Cubic cm		1.3079 x 10^{-6}		cu yd
Cubic cm		0.27093		drams (U.S., fluid)
Cubic cm		2.6417 x 10^{-4}		gal (U.S.)
Cubic cm		9.9997 x 10^{-4}		liters
Cubic cm		16.231		minims (U.S.)
Cubic cm		0.033814		ounces (U.S., fluid)

* Avogadro's number.

CONVERSION FACTORS (Continued)

Column A	x Column B	= Column C
Cubic cm	0.00211334	pints (U.S., liquid)
Cubic cm	9.0808 x 10^{-4}	quarts (U.S., dry)
Cubic cm	0.0010567	quarts (U.S., liquid)
Cubic cm atm (normal)	0.1013325	joules (Abs.)
Cubic cm/sec	0.0021186	cu ft/min
Cubic ft (U.S.)	28317	cu cm
Cubic ft (U.S.)	1728	cu in.
Cubic ft (U.S.)	0.02831701	cu m
Cubic ft (U.S.)	0.037037	cu yd
Cubic ft (U.S.)	7.481	gallons (U.S.)
Cubic ft (U.S.)	28.316	liters
Cubic ft (U.S.)	25.714	quarts (U.S., dry)
Cubic ft (U.S.)	29.922	quarts (U.S., liquid)
Cubic ft atm	680.74	gram calories (mean)
Cubic ft atm	2116.3	ft lb
Cubic ft atm	2869.4	joules (Abs.)
Cubic ft atm	292.59	kg m
Cubic ft atm	28.316	L atm
Cubic ft of water (60°F)	62.37	pounds
Cubic ft/min	472.0	cu cm/sec
Cubic ft/min	0.1247	gal/sec
Cubic ft/min	0.4720	L/sec
Cubic ft/sec	2.22222	cu yd/min
Cubic in. (U.S.)	4.65025 x 10^{-4}	bushels (U.S.)
Cubic in. (British)	16.3870253	cu cm
Cubic in. (U.S.)	16.387162	cu cm
Cubic in. (British)	5.7870 x 10^{-4}	cu ft (British)
Cubic in. (U.S.)	5.78704 x 10^{-4}	cu ft (U.S.)
Cubic in. (U.S.)	1.63871 x 10^{-5}	cu m
Cubic in. (U.S.)	2.143347 x 10^{-5}	cu yards
Cubic in. (U.S.)	4.43322	drams (fluid)
Cubic in. (U.S.)	0.0043290	gallons (U.S.)
Cubic in. (U.S.)	0.0163868	liters
Cubic in. (U.S.)	0.5541	ounces (fluid) (U.S.)
Cubic in. (U.S.)	0.00186010	pecks (U.S.)
Cubic in. (U.S.)	0.0297615	pints (U.S., dry)
Cubic in. (U.S.)	0.0148808	quarts (U.S., dry)
Cubic in. (U.S.)	0.017316	quarts (U.S., liquid)
Cubic km	1 x 10^{9}	cu m
Cubic m	28.3776	bushels (U.S.)
Cubic m	1 x 10^{6}	cu cm
Cubic m	35.314445	cu ft (U.S.)
Cubic m	61023	cu in.
Cubic m	1.3079428	cu yd (U.S.)
Cubic m	999.973	liters
Cubic m	2113.4	pints (U.S., liquid)
Cubic m	1056.7	quarts (U.S., liquid)
Cubic mm	6.1023 x 10^{-5}	cu in.
Cubic mm	1 x 10^{-9}	cu m
Cubic mm	0.016231	minims (U.S.)
Cubic yd	764559.45	cu cm
Cubic yd (U.S.)	27	cu ft
Cubic yd (U.S.)	46656	cu in.
Cubic yd (U.S.)	0.76455945	cu m
Cubic yd (U.S.)	202.0	gallons (U.S.)
Cubic yd	764.54	liters
Cubic yd (U.S.)	1616	pints (U.S., liquid)
Cubic yd (U.S.)	807.9	quarts (U.S., liquid)
Days (mean solar)	24	hours (mean solar)
Days (mean solar)	1440	minutes (mean solar)
Days (mean solar)	86400	seconds (mean solar)
Days (sidérial)	86164	seconds (mean solar)
Degrees	0.00277778	circumferences
Degrees	60	minutes
Degrees	1/90	quadrants
Degrees	0.0174533	radians
Degrees	0.00277778	revolutions
Degrees	3600	seconds
Degrees/sec	0.1667	revolutions/min
Degrees/sec	0.002778	revolutions/sec
Drams (apothecaries' or troy)	2.194286	drams (avoirdupois)
Drams (apothecaries' or troy)	60	grains
Drams (apothecaries' or troy)	3.8879351	grams
Drams (apothecaries' or troy)	0.1371429	ounces (avoirdupois)
Drams (apothecaries' or troy)	0.125	ounces (troy)
Drams (troy)	2.5	pennyweights
Drams (apothecaries' or troy)	0.008571429	pounds (avoirdupois)
Drams (apothecaries' or troy)	1/96	pounds (troy)
Drams (avoirdupois)	0.4557292	drams (apothecaries' or troy)
Drams (avoirdupois)	27.34375	grains
Drams (avoirdupois)	1.771845	grams
Drams (avoirdupois)	0.0625	ounces (avoirdupois)
Drams (avoirdupois)	0.056966146	ounces (troy)
Drams (avoirdupois)	1/256	pounds (avoirdupois)
Drams (avoirdupois)	0.0047471788	pounds (troy)
Drams (U.S., fluid or apoth.)	3.6967	cu cm
Drams (U.S., fluid or apoth.)	0.225570	cu in.
Drams (U.S., fluid or apoth.)	3.6966	milliliters
Drams (U.S., fluid or apoth.)	60	minims (U.S., fluid)
Drams (U.S., fluid or apoth.)	0.125	ounces (fluid)
Dynes	0.015368	grains
Dynes	0.00101972	grams
Dynes	2.2481 x 10^{-6}	pounds
Dyne-cm (torque)	1.0197 x 10^{-8}	kg m
Dyne-cm (torque)	7.3757 x 10^{-8}	lb ft
Dyne-cm (torque)	8.8511 x 10^{-7}	lb in.
Dynes/cm	1	ergs/sq cm
Dynes/cm	0.01	ergs/sq mm
Dynes/cm	2.5901	mg/in.
Dynes/cm	0.10197	mg/mm
Dynes/sq cm	9.8692 x 10^{-7}	atm
Dynes/sq cm	2.9530 x 10^{-5}	in. Hg at 32°F
Dynes/sq cm	4.0168 x 10^{-4}	in. of water at 39.2°F. (4°C.)
Dynes/sq cm	0.0101971	kg/sq m
Dynes/sq cm	7.5006 x 10^{-4}	mm Hg
Dynes/sq cm	0.0020886	lb/sq ft
Dynes/sq cm	1.4504 x 10^{-5}	lb/sq in.
Electromagnetic cgs unit of field strength	1.0000	gauss (Abs.)
Electromagnetic cgs units of magnetic permeability	8.9916 x 10^{20}	electrostatic cgs units of magnetic permeability
Electromagnetic cgs units of mass resistance	9.9948 x 10^{-6}	ohm, International-meter-gram
Electromagnetic cgs units of reluctance	1.0000	oersteds (Abs.)
Electronic charges	1.5921 x 10^{-20}	abcoulombs
Electronic charges	1.5921 x 10^{-19}	coulombs (Abs.)
Electronic charges	4.774 x 10^{-10}	statcoulombs
Electrons/kg	4.868 x 10^{-16}	statcoulombs/dyne
Electrostatic cgs units of field strength	3.33560 x 10^{-11}	gauss (Abs.)
Ergs	9.4805 x 10^{-11}	BTU (mean)
Ergs	2.3889 x 10^{-8}	gram calories (mean)
Ergs	2.3889 x 10^{-11}	kg calories (mean)
Ergs	7.3756 x 10^{-8}	ft lb
Ergs	0.00101972	g cm
Ergs	1 x 10^{-7}	joules
Ergs	1.0197 x 10^{-8}	kg m
Ergs/sec	5.6883 x 10^{-9}	BTU (mean)/min
Ergs/sec	1.4333 x 10^{-9}	kg calories (mean)/min
Ergs/sec	4.4254 x 10^{-6}	ft lb/min
Ergs/sec	7.3756 x 10^{-8}	ft lb/sec
Ergs/sec	1.3410 x 10^{-10}	horse power
Ergs/sec	1 x 10^{-10}	KW
Ergs/sec	1 x 10^{-7}	watts
Ergs/sq cm	1	dynes/cm
Ergs/sq cm	0.01	ergs/sq mm
Ergs/sq mm	100	dynes/cm
Ergs/sq mm	100	ergs/sq cm
Faradays	9.6500 x 10^{4}	coulombs (Abs.)
Faradays	9.6507 x 10^{4}	coulombs (International)
Faradays/kg	2.9507 x 10^{8}	statcoulombs/dyne
Faradays/sec	96500	amperes (Abs.)
Farads (Abs.)	1 x 10^{-9}	Abfarads
Farads (Abs.)	1.00052	farads (International)
Farads (Abs.)	1 x 10^{6}	microfarads
Farads (Abs.)	8.98776 x 10^{11}	statfarads
Farads (International)	0.99948	farads (Abs.)
Fathoms	6	feet
Feet (U.S.)	30.48006096	centimeters
Feet (U.S.)	0.3048006096	meters
Feet (U.S.)	1.6447 x 10^{-4}	miles (nautical)
Feet (U.S.)	1.893939 x 10^{-4}	miles (statute)
Feet (U.S.)	473404	wave lengths of red line of cadmium
Feet of water at 39.2°F. (4°C.)	0.029499	atm
Feet of water at 39.2°F. (4°C.)	0.88265	in. Hg at 32°F. (0°C.)

CONVERSION FACTORS (Continued)

Column A	×	Column B	÷	Column C
Feet of water at 39.2°F (4°C.)	×	304.79		kg/sq m
Feet of water at 39.2°F (4°C.)	×	0.43352		lb/sq in.
Feet of water at 39.2°F (4°C.)	×	62.427		lb/sq ft
Feet/min	×	0.508001		cm/sec
Feet/min	×	0.01829		km/hr
Feet/min	×	0.00508001		mi/sec
Feet/min	×	0.011364		m/hr
Feet/sec	×	1.0973		km/hr
Feet/sec	×	0.5921		knots/hr
Feet/sec	×	18.29		m/min
Feet/sec	×	0.6818		mi/hr
Feet/sec	×	0.011364		mi/min
Feet/sec^2	×	1.0973		km/hr/sec
Foot candles	×	10.764		lumens/sq m
Foot pounds	×	0.32389		gram calories (mean)
Foot pounds	×	4.7253 x 10^{-4}		cu ft atm
Foot pounds	×	1.35582 x 10^{7}		ergs
Foot pounds	×	1.3825 x 10^{4}		g cm
Foot pounds	×	5.0505 x 10^{-7}		horse power hr
Foot pounds	×	1.35582		joules (Abs.)
Foot pounds	×	0.138255		kg m
Foot pounds	×	3.7662 x 10^{-7}		KW hr
Foot pounds	×	0.013381		L atm
Foot pounds/min	×	2.2597 x 10^{-5}		KW
Foot pounds/sec	×	0.0018182		horse power
Foot pounds/sec	×	0.001355582		KW
Foot pounds/sec	×	1.35582		watts (Abs.)
Gallons (U.S.)	×	3785.4		cu cm
Gallons (U.S.)	×	0.13368		cu ft
Gallons (U.S.)	×	231		cu in.
Gallons (U.S.)	×	0.0037854		cu m
Gallons (U.S.)	×	0.004951		cu yd
Gallons (U.S.)	×	3.78533		liters
Gallons (U.S.)	×	61440		minims
Gallons (U.S.)	×	128		ounces (U.S., fluid)
Gallons (U.S.)	×	8		pints (U.S., liquid)
Gallons (U.S.)	×	8.3378		pounds (avoirdupois) of water at 62°F (16.7°C)
Gallons (U.S.)	×	4		quarts (U.S., liquid)
Gallons (U.S.) water/min	×	6.0086		tons water/24 hours
Gallons (U.S.)/min	×	8.0208		cu ft/hr
Gallons (U.S.)/min	×	0.002228		cu ft/sec
Gallons (U.S.)/min	×	0.06308		L/sec
Grains	×	63.5453		dynes
Grains	×	0.064798918		grams
Grains	×	64.798918		milligrams
Grains	×	0.0022857		ounces (avoirdupois)
Grains	×	0.0020833		ounces (troy)
Grains	×	1/7000		pounds (avoirdupois)
Grains	×	1/5760		pounds (troy)
Grams	×	980.665		dynes
Grams	×	15.4324		grains
Grams	×	1 x 10^{6}		micrograms
Grams	×	1000		milligrams
Grams	×	0.0352739		ounces (avoirdupois)
Grams	×	0.0321507		ounces (troy)
Grams	×	0.00220462		pounds (avoirdupois)
Grams	×	0.00267923		pounds (troy)
Grams	×	1 x 10^{-6}		tons (metric)
Gram centimeters	×	2.3427 x 10^{-5}		gram calories (mean)
Gram centimeters	×	980.665		ergs
Gram centimeters	×	7.233 x 10^{-5}		ft lb
Gram centimeters	×	9.80665 x 10^{-5}		joules (Abs.)
Gram centimeters	×	1 x 10^{-5}		kg m
Gram centimeters/sec	×	9.80665 x 10^{-5}		watts (Abs.)
Gram sq cm (moment of inertia)	×	2.37305 x 10^{-6}		lb/sq ft
Gram sq cm (moment of inertia)	×	3.4172 x 10^{-4}		lb/sq in.
Grams/cu cm	×	62.43		lb/cu ft
Grams/cu cm	×	0.03613		lb/cu in.
Grams/cu cm	×	8.3454		lb/gal (U.S.)
Grams/cu m	×	0.35757		grains/cu ft
Grams/L	×	58.417		grains/gal (U.S.)
Grams/L	×	1000		parts per million
Grams/L	×	0.062427		lb/cu ft
Grams/L	×	8.345		lb/1000 gal (U.S.)
Grams/ml	×	0.999973		g/cu cm
Grams/sq cm	×	9.6784 x 10^{-4}		atm
Grams/sq cm	×	980.665		dynes/sq cm
Grams/sq cm	×	10		kg/sq m
Grams/sq cm	×	0.73556		mm Hg at 0°C
Grams/sq cm	×	2.04817		lb/sq ft

Column A	×	Column B	÷	Column C
Grams/sq cm	×	0.0142234		lb/sq in.
Gravity	×	980.665		cm/sec^2
Gravity	×	32.174		ft/sec^2
Hectares	×	2.471044		acres (U.S.)
Hectares	×	10,000		sq m
Hectares	×	11959.85		sq yd (U.S.)
Horse power	×	42.418		BTU (mean)/min
Horse power	×	10.688		kg calories (mean)/min
Horse power	×	33,000		ft lb/min
Horse power	×	550		ft lb/sec
Horse power	×	1.0139		horse power (metric)
Horse power	×	0.74570		KW
Horse power	×	745.70		watts
Horse power (metric)	×	32549		ft lb/min
Horse power (metric)	×	0.98632		horse power (U.S.)
Horse power (metric)	×	75		kg m/sec
Horse power hr	×	641.304		kg calories (mean)
Horse power hr	×	1.9800 x 10^{6}		ft lb
Horse power hr	×	2.6845 x 10^{6}		joules (Abs.)
Horse power hr	×	2.7374 x 10^{5}		kg m
Horse power hr	×	0.7457		KW hr
Hours (mean solar)	×	0.041667		days (mean solar)
Hours (mean solar)	×	0.0059524		weeks
Inches (U.S.)	×	2.5400 x 10^{8}		angstrom units
Inches (U.S.)	×	2.540005		centimeters
Inches (U.S.)	×	1.57828 x 10^{-5}		miles
Inches (U.S.)	×	39450.45		wave length of the red line of cadmium
Inches Hg at 32°F	×	0.033421		atm
Inches Hg at 32°F	×	3.38639 x 10^{4}		dynes/sq cm
Inches Hg at 32°F	×	345.31		kg/sq m
Inches Hg at 32°F	×	70.727		lb/sq ft
Inches of water at 39.2°F (4°C)	×	0.0024583		atm
Inches of water at 39.2°F (4°C)	×	2490.82		dynes/sq cm
Inches of water at 39.2°F (4°C)	×	25.399		kg/sq m
Inches of water at 39.2°F (4°C)	×	5.2022		lb/sq ft
Joules (Abs.)	×	9.480 x 10^{-4}		BTU (mean)
Joules (Abs.)	×	0.23895		gram calories (mean)
Joules (Abs.)	×	0.23918		gram calories (20°C)
Joules (Abs.)	×	2.3889 x 10^{-4}		kg calories (mean)
Joules (Abs.)	×	3.485 x 10^{-4}		cu ft atm
Joules (Abs.)	×	1 x 10^{7}		ergs
Joules (Abs.)	×	0.73756		ft lb
Joules (Abs.)	×	1.0197 x 10^{4}		g cm
Joules (Abs.)	×	3.72508 x 10^{-7}		horse power hr
Joules (Abs.)	×	0.999480		joules (International)
Joules (Abs.)	×	0.101972		kg m
Joules (Abs.)	×	2.77778 x 10^{-7}		KW hr
Joules (Abs.)	×	0.0098689		L atm
Joules/°C	×	5.2679 x 10^{-4}		BTU (60°F)/°F
Joules/°C	×	0.23889		gram calories/°C
Joules/electron	×	6.2811 x 10^{18}		joules/abcoulomb
Joules/electron/°C	×	6.2811 x 10^{18}		joules/coulombs/°C
Joules/farday	×	1.0363 x 10^{-5}		joules/abcoulomb
Joules/farday/°C	×	1.0363 x 10^{-5}		joules/coulomb/°C
Joules/gram/°C	×	0.23889		gram calories (mean)/g/°C
Joule seconds	×	1.5258 x 10^{33}		quanta
Joule seconds/N_0*	×	2.5173 x 10^{9}		quanta
Kilograms	×	9.80665 x 10^{5}		dynes
Kilograms	×	2.20462341		pounds (avoirdupois)
Kilograms	×	2.6792285		pounds (troy)
Kilogram meters	×	0.00929667		BTU (mean)
Kilogram meters	×	2.3427		gram calories (mean)
Kilogram meters	×	0.0034177		cu ft atm
Kilogram meters	×	9.80665 x 10^{7}		ergs
Kilogram meters	×	232.71		foot poundals
Kilogram meters	×	7.2330		ft lb
Kilogram meters	×	3.6529 x 10^{-6}		horse power hr
Kilogram meters	×	2.72407 x 10^{-6}		KW hr
Kilograms/m	×	0.67197		lb/ft
Kilograms/sq cm	×	73.556		cm Hg at 0°C
Kilograms/sq cm	×	14.223		lb/sq in.
Kilograms/sq m	×	9.6777 x 10^{-5}		atm
Kilograms/sq m	×	98.065		dynes/sq cm
Kilograms/sq m	×	0.0032809		ft of water
Kilograms/sq m	×	0.1		g/sq cm
Kilograms/sq m	×	0.0028959		in. Hg
Kilograms/sq m	×	0.073556		mm Hg
Kilograms/sq m	×	0.204817		lb/sq ft
Kilograms/sq m	×	0.00142234		lb/sq in.
Kilograms/sq mm	×	9.80665 x 10^{7}		dynes/sq cm
Kiloliters	×	35.317		cu ft

* Avogadro's number.

CONVERSION FACTORS (Continued)

Column A	× Column B	= Column C
Kilometers	3280.83	feet
Kilometers	0.539593	miles (nautical)
Kilometers	0.6213699495	miles (U.S.)
Kilometers	0.1	myriameters
Kilometers	1093.6	yards
Kilometers/hr	27.7778	cm/sec
Kilometers/hr	54.68	ft/min
Kilometers/hr	0.9113	ft/sec
Kilometers/hr	0.5396	knots/hr
Kilometers/hr	16.667	m/min
Kilometers/hr	0.27778	m/sec
Kilometers/hr/sec	27.778	cm/sec^2
Kilometers/hr/sec	0.9113	ft/sec^2
Kilometers/hr/sec	0.27778	m/sec^2
Kilometers/min	1666.7	cm/sec
Kilometers/min	37.2822	mi/hr
Kilowatt hours	3413.0	BTU (mean)
Kilowatt hours	8.6001×10^5	gram calories (mean)
Kilowatt hours	2.6552×10^6	ft lb
Kilowatt hours	1.3410	horse power hr
Kilowatt hours	3.6000×10^6	joules (Abs.)
Kilowatt hours	3.6709×10^5	kg m
Kilowatts	56.884	BTU (mean)/min
Kilowatts	14.3334	kg calories (mean)/min
Kilowatts	2.6552×10^6	ft lb/hr
Kilowatts	1.3410	horse power
Knots/hr	51.479	cm/sec
Knots/hr	1.1515	mi/hr
Lamberts	0.3183	candles/sq cm
Lamberts	2.054	candles/sq in.
Lamberts	1	lumens emitted/sq cm (perfectly diffusing surface)
Liter atmospheres (normal)	24.206	gram calories (mean)
Liter atmospheres (normal)	0.035316	cu ft atm
Liters	0.028378	bushels (U.S.)
Liters	0.035316	cu ft
Liters	61.025	cu in.
Liters	0.001000027	cu m
Liters	0.0013080	cu yd
Liters	270.5179	drams (U.S., fluid)
Liters	0.26417762	gallons (U.S.)
Liters	33.8143	ounces (U.S., fluid)
Liters	1.816192	pints (U.S., dry)
Liters	2.11336	pints (U.S., liquid)
Liters	0.908096	quarts (U.S., dry)
Liters	1.056681869	quarts (U.S., liquid)
Liters/cm/da	0.011574	sq cm/sec
Liters/min	5.886×10^{-4}	cu ft/sec
Liters/min	0.004403	gal/sec
Liters/sec	2.11896	cu ft/min
Liters/sec	15.8507	gallons (U.S.)/min
Lumens	0.001496	watts
Lumens/sq ft	1	foot candles
Lumens/sq ft	10.764	lumens/sq m
Lumens/sq m	0.092902	foot candles (lumens)/ sq ft
Lumens/sq m	1×10^{-4}	phots
Megmhos	0.001	abmohs
Megmhos	2.540	megmhos/cu in.
Megmhos/cu in.	0.39370	megmhos/cu cm
Mercury at 0°C	13.5951	g/cu cm
Meter candles	1.000	lumens/sq m
Meters	1×10^{10}	angstrom units
Meters	3.280833333	feet (U.S.)
Meters	39.3700	inches (U.S.)
Meters	5.3993×10^{-4}	miles (nautical)
Meters	6.2137×10^{-4}	miles (statute)
Meters	1×10^9	millimicrons
Meters	1×10^{12}	millionth microns
Meters	1.55316412×10^6	wave lengths of the red line of cadmium
Meters	1.093611	yards (U.S.)
Meters/min	1.6667	cm/sec
Meters/min	0.05468	ft/sec
Meters/min	0.06	km/hr
Meters/min	0.03728	mi/hr
Meters/sec	196.8	ft/min
Meters/sec	3.6000	km/hr
Meters/sec	0.060000	km/min
Meters/sec	2.2369	mi/hr
Meters/sec	0.03728	mi/min
Meters/sec^2	3.6	km/hr/sec
Meters/sec^2	2.2369	mi/hr/sec

Column A	× Column B	= Column C
Mhos, International/cu cm	0.99948	mhos (Abs.)/cu cm
Microfarads	1×10^{-15}	abfarads
Microns	1×10^4	angstrom units
Microns	1×10^{-4}	centimeters
Microns	3.937×10^{-5}	inches
Microns	0.001	millimeters
Microvolts/°F	1.8000	microvolts/°C
Miles (nautical)	6080.20	feet
Miles (nautical)	1.85325	kilometers
Miles (U.S., statute)	63360	inches
Miles (U.S., statute)	5280	feet
Miles (U.S., statute)	1.609347219	kilometers
Miles/hr	44.7041	cm/sec
Miles/hr	88	ft/min
Miles/hr	1.4667	ft/sec
Miles/hr	0.8684	knots/hr
Miles/hr	26.82	m/min
Miles/hr/min	0.74507	cm/sec^2
Miles/hr/sec	44.704	cm/sec^2
Miles/hr/sec	1.4667	ft/sec^2
Miles/hr/sec	0.44704	m/sec^2
Miles/min	2682.2	cm/sec
Miles/min	88	ft/sec
Milligrams	0.01543236	grains
Milligrams	5.64383×10^{-4}	drams (avoirdupois)
Milligrams	2.57206×10^{-4}	drams (troy)
Milligrams	3.52739×10^{-5}	ounces (avoirdupois)
Milligrams	3.215074×10^{-5}	ounces (troy)
Milligrams	2.2046×10^{-6}	pounds (avoirdupois)
Milligrams	2.67923×10^{-6}	pounds (troy)
Milligrams/in.	0.38609	dynes/cm
Milligrams/L	1.0	parts per million
Milligrams/mm	9.80665	dynes/cm
Millilamberts	0.929	lumens emitted/sq ft (with perfect diffusion)
Milliliters	1.000027	cu cm
Milliliters	0.061025	cu in.
Milliliters	0.2705179	drams (U.S., fluid)
Milliliters	16.2311	minims (U.S.)
Milliliters	0.0338147	ounces (U.F., fluid)
Millimeters	0.0393700	inches (U.S.)
Millimeters Hg at 0°C	0.001315579	atm
Millimeters Hg at 0°C	1333.22	dynes/sq cm
Millimeters Hg at 0°C	1.3595	g/sq cm
Millimeters Hg at 0°C	13.595	kg/sq m
Millimeters Hg at 0°C	1000	microns Hg at 0°C
Millimeters Hg at 0°C	2.7845	lb/sq ft
Millimeters Hg at 0°C	0.019337	lb/sq in.
Millimicrons (micro-millimeters)	10	angstrom units
Millimicrons	1×10^{-7}	centimeters
Minims (U.S., fluid)	0.0616112	cubic cm
Minims (U.S.)	61.612	cubic cm
Minims (U.S.)	1/60	drams (U.S., fluid)
Minims (U.S.)	0.0616102	milliliters
Minims (U.S.)	1/480	ounces (U.S., fluid)
Minutes (time)	6.94444×10^{-4}	days
Minutes (time)	9.9206×10^{-5}	weeks
Months (mean calender)	30.4202	days
Months (mean calender)	730.085	hours
Months (mean calender)	43805.1	minutes
Months (mean calender)	2.6283×10^6	seconds
Oersteds (Abs.)	1.00052	oersteds (International)
Ohm-mile-pounds	1.7513×10^{-4}	ohm-meter-grams
Ohms (Abs.)	0.99948	ohms (International)
Ounces (avoirdupois)	16	drams (avoirdupois)
Ounces (avoirdupois)	7.29166	drams (troy or apoth.)
Ounces (avoirdupois)	437.5	grains
Ounces (avoirdupois)	28.349527	grams
Ounces (avoirdupois)	0.9114583	ounces (troy or apoth.)
Ounces (avoirdupois)	1/16	pounds (avoirdupois)
Ounces (avoirdupois)	0.075954861	pounds (troy)
Ounces (troy or apoth.)	17.55428	drams (avoirdupois)
Ounces (troy or apoth.)	8	drams (troy or apoth.)
Ounces (troy or apoth.)	480	grains
Ounces (troy or apoth.)	31.103481	grams
Ounces (troy or apoth.)	1.09714	ounces (avoirdupois)
Ounces (troy or apoth.)	0.06857143	pounds (avoirdupois)
Ounces (troy or apoth.)	1/12	pounds (troy)
Ounces (U.S., fluid)	29.5737	cu cm
Ounces (U.S., fluid)	1.80469	cu in.
Ounces (U.S., fluid)	8	drams (fluid)
Ounces (U.S., fluid)	1/128	gallons (U.S.)
Ounces (U.S., fluid)	0.0295729	liters
Ounces (U.S., fluid)	480	minims (U.S.)
Ounces (U.S., fluid)	1/16	pints (U.S., liquid)

CONVERSION FACTORS (Continued)

Column A	x	Column B	=	Column C
Pints (U.S., dry)		0.015625		bushels (U.S.)
Pints (U.S., dry)		550.61		cu cm
Pints (U.S., dry)		33.6003		cu in.
Pints (U.S., dry)		0.550599		liters
Pints (U.S., dry)		0.5		quarts (U.S., dry)
Pints (U.S., liquid)		473.179		cu cm
Pints (U.S., liquid)		0.016711		cu ft
Pints (U.S., liquid)		28.875		cu in.
Pints (U.S., liquid)		6.1881×10^{-4}		cu yd
Pints (U.S., liquid)		128		drams (fluid)
Pints (U.S., liquid)		0.125		gallons (U.S.)
Pints (U.S., liquid)		0.473168		liters
Pints (U.S., liquid)		7680		minims (U.S.)
Pints (U.S., liquid)		16		ounces (U.S., fluid)
Pints (U.S., liquid)		0.5		quarts (U.S., liquid)
Planck's quanta		6.554×10^{-27}		erg seconds
Poises		1.000		g/cm/sec
Pounds (avoirdupois)		256		drams (avoirdupois)
Pounds (avoirdupois)		116.6667		drams (troy)
Pounds (avoirdupois)		4.44852×10^{5}		dynes
Pounds (avoirdupois)		7000		grains
Pounds (avoirdupois)		453.5924277		grams
Pounds (avoirdupois)		0.4535924277		kilograms
Pounds (avoirdupois)		16		ounces (avoirdupois)
Pounds (avoirdupois)		14.5833		ounces (troy)
Pounds		32.174		poundals
Pounds (avoirdupois)		1.2152778		pounds (troy)
Pounds (avoirdupois)		4.464286×10^{-4}		tons (long)
Pounds (avoirdupois)		4.5359243×10^{-4}		tons (metric)
Pounds (avoirdupois)		5×10^{-4}		tons (short)
Pounds (troy)		210.6514		drams (avoirdupois)
Pounds (troy)		96		drams (troy)
Pounds (troy)		5760		grains
Pounds (troy)		373.2418		grams
Pounds (troy)		13.165714		ounces (avoirdupois)
Pounds (troy)		12		ounces (troy)
Pounds (troy)		0.822857		pounds (avoirdupois)
Pounds (troy)		3.6735×10^{-4}		tons (long)
Pounds (troy)		3.7324×10^{-4}		tons (metric)
Pounds (troy)		4.1143×10^{-4}		tons (short)
Pounds of water (62°F.)		0.016033		cu ft
Pounds of water		27.68		cu in.
Pounds of water		0.1198		gallons (U.S.)
Pounds/cu in.		27.68		g/cu cm
Pounds/ft		1.48816		kg/m
Pounds/in.		178.6		g/cm
Pounds/sq ft (moment of inertia)		4.2140×10^{5}		g/sq cm
Pounds/sq ft (moment of inertia)		421.40		kg/sq cm
Pounds/sq ft (moment of inertia)		144		lb/sq in.
Pound feet (torque)		1.3558×10^{7}		dyne cm
Pounds/sq in. (moment of inertia		2926.4		g/sq cm
Pounds/sq in. (moment of inertia		2.9264		kg/sq cm
Pounds/sq in. (moment of inertia)		0.00694444		lb/sq ft
Pound inches (torque)		1.1298×10^{6}		dyne cm
Pounds of water/min		0.016021		cu ft/min
Pounds of water/min		2.670×10^{-4}		cu ft/sec
Pounds/cu ft		0.016018		g/cu cm
Pounds/cu ft		16.018		kg/cu m
Pounds/cu in.		5.787×10^{-4}		lb/cu in.
Pounds/cu in.		27.6800		g/cu cm
Pounds/cu ln.		2.768×10^{4}		kg/cu m
Pounds/gal (British)		0.099776		g/cu cm
Pounds/gal (U.S.)		0.119826		g/cu cm
Pounds/sq ft		4.7252×10^{-4}		atm
Pounds/sq ft		478.78		dynes/sq cm
Pounds/sq ft		0.016018		ft of water at 39.1°F
Pounds/sq ft		0.48824		g/sq cm
Pounds/sq ft		4.8824		kg/sq m
Pounds/sq ft		0.35913		mm of Hg at 0°C
Pounds/sq ft		0.0069445		lb/sq in.
Pounds/sq in.		0.0680646		atm
Pounds/sq in.		68946		dynes/sq cm
Pounds/sq in.		70.307		g/sq cm
Pounds/sq in.		27.673		in. of water at 39.2°F (4°C)
Pounds/sq in.		0.070307		kg/sq cm
Pounds/sq in./		703.07		kg/sq m
Pounds/sq in.		51.715		mm of Hg
Pounds/sq in.		144		lb/sq ft
Quarts (U.S., dry)		0.03125		bushels (U.S.)
Quarts (U.S., dry)		1101.23		cubic cm

Column A	x	Column B	=	Column C
Quarts (U.S., dry)		0.038889		cubic ft
Quarts (U.S., dry)		67.2006		cubic in.
Quarts (U.S., dry)		1.10120		liters
Quarts (U.S., dry)		0.125		pecks (U.S.)
Quarts (U.S., dry)		2		pints (dry)
Quarts (U.S., liquid)		946.358		cubic cm
Quarts (U.S., liquid)		57.749		cubic in.
Quarts (U.S., liquid)		0.033420		cu ft
Quarts (U.S., liquid)		256.00		drams (fluid)
Quarts (U.S., liquid)		0.25		gallons (U.S.)
Quarts (U.S., liquid)		0.946333		liters
Quarts (U.S., liquid)		32		ounces (fluid, U.S.)
Quarts (U.S., liquid)		1.96841		quintals (metric)
Square centimeters		0.0010764		sq ft
Square centimeters		0.15500		sq in.
Square centimeters		0.0024710 7		sq. links (Gunter's)
Square centimeters		1×10^{-4}		sq m
Square centimeters		100		sq mm
Square centimeters		1.1960×10^{-4}		sq yd
Square centimeters/day		1.1574×10^{-5}		sq cm/sec
Square feet (U.S.)		2.29568×10^{-5}		acres
Square feet		929.0341		sq cm
Square feet (U.S.)		144		sq in.
Square feet (U.S.)		0.09290341		sq m
Square feet (U.S.)		3.58701×10^{-8}		sq mi
Square feet (U.S.)		1/9		sq yd (U.S.)
Square inches (U.S.)		6.4516258		sq cm
Square inches (U.S.)		1/144		sq ft (U.S.)
Square inches (U.S.)		6.4516258×10^{-4}		sq m
Square inches (U.S.)		1/1296		sq yd (U.S.)
Square kilometers		247.1044		acres (U.S.)
Square kilometers		1.0764×10^{7}		sq ft
Square kilometers		1×10^{6}		sq m
Square kilometers		0.3861006		sq mi(U.S.)
Square kilometers		1.1960×10^{6}		sq yd
Square meters		2.471044×10^{-4}		acres (U.S.)
Square meters		1×10^{4}		sq cm
Square meters		10.76387		sq ft (U.S.)
Square meters		1550.0		sq. in.
Square meters		1×10^{-6}		sq km
Square meters		1×10^{6}		sq mm
Square meters		3.8610×10^{-7}		sq mi
Square meters		1.195985		sq yd (U.S.)
Square miles		640		acres
Square miles		2.78784×10^{7}		sq ft
Square miles		2.589998		sq km
Square miles		2589998		sq m
Square miles		3.0976×10^{6}		sq yd
Square millimeters		0.01		sq cm
Square millimeters		0.0015500		sq in.
Square millimeters		1×10^{-6}		sq m
Square mils		6.4516×10^{-6}		sq cm
Square mils		1×10^{-6}		sq in.
Square mils		6.4516×10^{-4}		sq mm
Square yards (U.S.)		2.06612 x 10^{-4}		acres (U.S.)
Square yards (U.S.)		8361.31		sq cm
Square yards (U.S.)		9		sq ft
Square yards (U.S.)		1296		sq in.
Square yards (U.S.)		0.83613		sq m
Square yards (U.S.)		3.22831×10^{-7}		sq mi
Statamperes		3.33560×10^{-10}		amperes (Abs.)
Statcoulombs		3.33560×10^{-10}		coulombs (Abs.)
Statcoulombs		2.0947×10^{9}		electronic charges
Statcoulombs/kg		1.0197×10^{-6}		statcoulombs/dyne
Statcoulombs/lb		2.2481×10^{-6}		statcoulombs/dyne
Statfarads		1.11263×10^{-12}		farads (Abs.)
Statfhenries		8.98776×10^{11}		henries (Abs.)
Statmhos		1.11263×10^{-12}		mohs, International/cu cm
Statohms		8.98776×10^{11}		ohms (Abs.)
Statvolts		299.796		volts (Abs.)
Tons (long)		1016.0470		kilograms
Tons (long)		2240		pounds (avoirdupois)
Tons (long)		4722.22		pounds (troy)
Tons (metric)		1000		kilograms
Tons (metric)		2204.62		pounds (avoirdupois)
Tons (short)		8.8964×10^{8}		dynes
Tons (short)		907.1846		kilograms
Tons (short)		2000		pounds (avoirdupois)
Tons (short)		2430.56		pounds (troy)
Tons (short)		0.892857		tons (long)
Tons (short)		0.907185		tons (metric)
Tons (short)/sq ft		0.94509		atmospheres
Volts (Abs.)		1×10^{8}		abvolts
Volts/°C		1.0000		joules/coulomb/°C
Volts (Abs.)		0.0033356		statvolts
Volts (Abs.)		0.99955		volts (International)

CONVERSION FACTORS (Concluded)

Column A	x	Column B	x	Column C
Watt hours	3.4130	BTU (mean)		
Watt hours	860.01	calories, g (mean)		
Watt hours	0.86001	Calories, kg (mean)		
Watt hours	2655.3	foot pounds		
Watt hours	0.0013410	horse power hr		
Watt hours	3600	joules		
Watt hours	367.09	kg meters		
Watts (Abs.)	0.014233	Calories, kg (mean)/min		
Watts (Abs.)	1 x 10^7	ergs/sec		
Watts (Abs.)	44.254	ft lb/min		
Watts (Abs.)	0.73756	ft lb/sec		
Watts (Abs.)	0.0013410	horse power		
Watts (Abs.)	0.0013596	horse power (metric)		

Column A	x	Column B	x	Column C
Watts (Abs.)	1	joules/sec		
Watts (International)	1.00032	watts (Abs.)		
Watts/sq in.	8.1913	BTU/sq ft/min		
Watts/sq in.	6372.6	ft lb/sq ft/min		
Watts/sq in.	0.19310	horse power		
Weeks	168	hours		
Weeks	10080	minutes		
Weeks	604800	seconds		
Yards (U.S.)	91.440183	centimeters		
Yards (U.S.)	5.6818 2 x 10^{-4}	miles		
Years (sidereal)	365.256	days (mean solar)		
Years (sidereal)	8766.144	hours (mean solar)		

ATOMIC WEIGHTS

Values in brackets are mass numbers of most stable isotopes.

Element	Symbol	Atomic No.	Atomic Wt.	Element	Symbol	Atomic No.	Atomic Wt.	Element	Symbol	Atomic No.	Atomic Wt.	Element	Symbol	Atomic No.	Atomic Wt.
Actinium	Ac	89	227	Erbium	Er	68	167.2	Neodymium	Nd	60	144.27	Scandium	Sc	21	44.96
Aluminum	Al	13	26.98	Europium	Eu	63	152.0	Neon	Ne	10	20.183	Selenium	Se	34	78.96
Americium	Am	95	[241]	Fluorine	F	9	19.00	Neptunium	Np	93	[237]	Silicon	Si	14	28.09
Antimony	Sb	51	121.76	Francium	Fr	87	[223]	Nickel	Ni	28	58.69	Silver	Ag	47	107.880
Argon	A	18	39.944	Gadolinium	Gd	64	156.9	Niobium (Columbium)	Nb	41	92.91	Sodium	Na	11	22.997
Arsenic	As	33	74.91	Gallium	Ga	31	69.72	Nitrogen	N	7	14.008	Strontium	Sr	38	87.63
Astatine	At	85	[210]	Germanium	Ge	32	72.60	Osmium	Os	76	190.2	Sulfur	S	16	32.066
Barium	Ba	56	137.36	Gold	Au	79	197.2	Oxygen	O	8	16.0000	Tantalum	Ta	73	180.88
Berkelium	Bk	97	[243]	Hafnium	Hf	72	178.6	Palladium	Pd	46	106.7	Technetium	Tc	43	[99]
Beryllium	Be	4	9.013	Helium	He	2	4.003	Phosphorus	P	15	30.975	Tellurium	Te	52	127.61
Bismuth	Bi	83	209.00	Holmium	Ho	67	164.94	Platinum	Pt	78	195.23	Terbium	Tb	65	159.2
Boron	B	5	10.82	Hydrogen	H	1	1.0080	Plutonium	Pu	94	[239]	Thallium	Tl	81	204.39
Bromine	Br	35	79.916	Indium	In	49	114.76	Polonium	Po	84	210	Thorium	Th	90	232.12
Cadmium	Cd	48	112.41	Iodine	I	53	126.91	Potassium	K	19	39.100	Thulium	Tm	69	169.4
Calcium	Ca	20	40.08	Iridium	Ir	77	193.1	Praseodymium	Pr	59	140.92	Tin	Sn	50	118.70
Californium	Cf	98	[244]	Iron	Fe	26	55.85	Promethium	Pm	61	[147]	Titanium	Ti	22	47.90
Carbon	C	6	12.010	Krypton	Kr	36	83.80	Protactinium	Pa	91	231	Tungsten (Wolfram)	W	74	183.92
Cerium	Ce	58	140.13	Lanthanum	La	57	138.92	Radium	Ra	88	226.05	Uranium	U	92	238.07
Cesium	Cs	55	132.91	Lead	Pb	82	207.21	Radon	Rn	86	222	Vanadium	V	23	50.95
Chlorine	Cl	17	35.457	Lithium	Li	3	6.940	Rhenium	Re	75	186.31	Xenon	Xe	54	131.3
Chromium	Cr	24	52.01	Lutetium	Lu	71	174.99	Rhodium	Rh	45	102.91	Ytterbium	Yb	70	173.04
Cobalt	Co	27	58.94	Magnesium	Mg	12	24.32	Rubidium	Rb	37	85.48	Yttrium	Y	39	88.92
Copper	Cu	29	63.54	Manganese	Mn	25	54.93	Ruthenium	Ru	44	101.7	Zinc	Zn	30	65.38
Curium	Cm	96	[242]	Mercury	Hg	80	200.61	Samarium	Sm	62	150.43	Zirconium	Zr	40	91.22
Dysprosium	Dy	66	162.46	Molybdenum	Mo	42	95.95								

WEIGHTS OF MULTIPLES

C = 12.01	H = 1.008	O = 16.000	N = 14.008	S = 32.066	P = 30.975	K = 39.100	Na = 22.997	Ca = 40.08	Mg = 24.32
2C = 24.02	2H = 2.016	2O = 32.000	2N = 28.016	2S = 64.132	2P = 61.950	2K = 78.200	2Na = 45.994	2Ca = 80.16	2Mg = 48.64
3C = 36.03	3H = 3.024	3O = 48.000	3N = 42.024	3S = 96.198	3P = 92.925	3K = 117.300	3Na = 68.991	3Ca = 120.24	3Mg = 72.96
4C = 48.04	4H = 4.032	4O = 64.000	4N = 56.032	4S = 128.264	4P = 123.900	4K = 156.400	4Na = 91.988	4Ca = 160.32	4Mg = 97.28
5C = 60.05	5H = 5.040	5O = 80.000	5N = 70.040	5S = 160.330	5P = 154.875	5K = 195.500	5Na = 118.985	5Ca = 200.40	5Mg = 121.60
6C = 72.06	6H = 6.048	6O = 96.000	6N = 84.048	6S = 192.396	6P = 185.850	6K = 234.600	6Na = 137.982	6Ca = 240.48	H_2O = 18.016
7C = 84.07	7H = 7.056	7O = 112.000	7N = 98.056	7S = 224.462	7P = 216.825	7K = 273.700	7Na = 160.979	7Ca = 280.56	$2H_2O$ = 36.032
8C = 96.08	8H = 8.064	8O = 128.000	8N = 112.064	8S = 256.528	8P = 247.800	8K = 312.800	8Na = 183.976	8Ca = 320.64	$3H_2O$ = 54.048
9C = 108.09	9H = 9.072	9O = 144.000	9N = 126.072	9S = 288.594	9P = 278.775	9K = 351.900	9Na = 206.973	9Ca = 360.72	$4H_2O$ = 72.064
10C = 120.10	10H = 10.080	10O = 160.000	10N = 140.080	10S = 320.660	10P = 309.750	10K = 391.000	10Na = 229.970	10Ca = 400.80	$5H_2O$ = 90.080

THERMOMETRIC EQUIVALENTS

$$^{\circ}C = \frac{5}{9}(^{\circ}F - 32), \quad ^{\circ}F = \frac{9}{5}\,^{\circ}C + 32$$

°F	(°C) Temp.	(°F)	°C	°F	(°C) Temp.	(°F)	°C	°F	(°C) Temp.	(°F)	°C	°F	(°C) Temp.	(°F)	°C
-40.0	- 40	-40.00	+35.6	+2	-16.67	+82.4	+28	-2.22	+129.2	+54	+12.22
-36.4	- 38	-38.89	+37.4	+3	-16.11	+84.2	+29	-1.67	+131.0	+55	+12.78
-32.8	- 36	-37.78	+39.2	+4	-15.56	+86.0	+30	-1.11	+132.8	+56	+13.33
-29.2	- 34	-36.67	+41.0	+5	-15.00	+87.8	+31	-0.56	+134.6	+57	+13.89
-25.6	- 32	-35.56	+42.8	+6	-14.44	+89.6	+32	±0.00	+136.4	+58	+14.44
-22.0	- 30	-34.44	+44.6	+7	-13.89	+91.4	+33	+0.56	+138.2	+59	+15.00
-18.4	- 28	-33.33	+46.4	+8	-13.33	+93.2	+34	+1.11	+140.0	+60	+15.56
-14.8	- 26	-32.22	+48.2	+9	-12.78	+95.0	+35	+1.67	+141.8	+61	+16.11
-11.2	- 24	-31.11	+50.0	+10	-12.22	+96.8	+36	+2.22	+143.6	+62	+16.67
-7.6	- 22	-30.00	+51.8	+11	-11.67	+98.6	+37	+2.78	+145.4	+63	+17.22
-4.0	- 20	-28.89	+53.6	+12	-11.11	+100.4	+38	+3.33	+147.2	+64	+17.78
-0.4	- 18	-27.78	+55.4	+13	-10.56	+102.2	+39	+3.89	+149.0	+65	+18.33
+3.2	- 16	-26.67	+57.2	+14	-10.00	+104.0	+40	+4.44	+150.8	+66	+18.89
+6.8	- 14	-25.56	+59.0	+15	-9.44	+105.8	+41	+5.00	+152.6	+67	+19.44
+10.4	- 12	-24.44	+60.8	+16	-8.89	+107.6	+42	+5.56	+154.4	+68	+20.00
+14.0	- 10	-23.33	+62.6	+17	-8.33	+109.4	+43	+6.11	+156.2	+69	+20.56
+17.6	- 8	-22.22	+64.4	+18	-7.78	+111.2	+44	+6.67	+158.0	+70	+21.11
+19.4	- 7	-21.67	+66.2	+19	-7.22	+113.0	+45	+7.22	+159.8	+71	+21.67
+21.2	- 6	-21.11	+68.0	+20	-6.67	+114.8	+46	+7.78	+161.6	+72	+22.22
+23.0	- 5	-20.56	+69.8	+21	-6.11	+116.6	+47	+8.33	+163.4	+73	+22.78
+24.8	- 4	-20.00	+71.6	+22	-5.56	+118.4	+48	+8.89	+165.2	+74	+23.33
+26.6	- 3	-19.44	+73.4	+23	-5.00	+120.2	+49	+9.44	+167.0	+75	+23.89
+28.4	- 2	-18.89	+75.2	+24	-4.44	+122.0	+50	+10.00	+168.8	+76	+24.44
+30.2	- 1	-18.33	+77.0	+25	-3.89	+123.8	+51	+10.56	+170.6	+77	+25.00
+32.0	+ 0	-17.78	+78.8	+26	-3.33	+125.6	+52	+11.11	+172.4	+78	+25.56
+33.8	+ 1	-17.22	+80.6	+27	-2.78	+127.4	+53	+11.67	+174.2	+79	+26.11

THERMOMETRIC EQUIVALENTS (Concluded)

°F	°C	Temp. (°F)	°C	Temp. (°F)	°C	Temp. (°F)	°C	Temp. (°F)	°C	Temp. (°F)	°C
+176.0	+80	+26.67	+237.2	+114	+45.56	+298.4	+148	+64.44	+359.6	+182	+83.33
+177.8	+81	+27.22	+239.0	+115	+46.11	+300.2	+149	+65.00	+361.4	+183	+83.89
+179.6	+82	+27.78	+240.8	+116	+46.67	+302.0	+150	+65.56	+363.2	+184	+84.44
+181.4	+83	+28.33	+242.6	+117	+47.22	+303.8	+151	+66.11	+365.0	+185	+85.00
+183.2	+84	+28.89	+244.4	+118	+47.78	+305.6	+152	+66.67	+366.8	+186	+85.56
+185.0	+85	+29.44	+246.2	+119	+48.33	+307.4	+153	+67.22	+368.6	+187	+86.11
+186.8	+86	+30.00	+248.0	+120	+48.89	+309.2	+154	+67.78	+370.4	+188	+86.67
+188.6	+87	+30.56	+249.8	+121	+49.44	+311.0	+155	+68.33	+372.2	+189	+87.22
+190.4	+88	+31.11	+251.6	+122	+50.00	+312.8	+156	+68.89	+374.0	+190	+87.78
+192.2	+89	+31.67	+253.4	+123	+50.56	+314.6	+157	+69.44	+375.8	+191	+88.33
+194.0	+90	+32.22	+255.2	+124	+51.11	+316.4	+158	+70.00	+377.6	+192	+88.89
+195.8	+91	+32.78	+257.0	+125	+51.67	+318.2	+159	+70.56	+379.4	+193	+89.44
+197.6	+92	+33.33	+258.8	+126	+52.22	+320.0	+160	+71.11	+381.2	+194	+90.00
+199.4	+93	+33.89	+260.6	+127	+52.78	+321.8	+161	+71.67	+383.0	+195	+90.56
+201.2	+94	+34.44	+262.4	+128	+53.33	+323.6	+162	+72.22	+384.8	+196	+91.11
+203.0	+95	+35.00	+264.2	+129	+53.89	+325.4	+163	+72.78	+386.6	+197	+91.67
+204.8	+96	+35.56	+266.0	+130	+54.44	+327.2	+164	+73.33	+388.4	+198	+92.22
+206.6	+97	+36.11	+267.8	+131	+55.00	+329.0	+165	+73.89	+390.2	+199	+92.78
+208.4	+98	+36.67	+269.6	+132	+55.56	+330.8	+166	+74.44	+392.0	+200	+93.33
+210.2	+99	+37.22	+271.4	+133	+56.11	+332.6	+167	+75.00	+393.8	+201	+93.89
+212.0	+100	+37.78	+273.2	+134	+56.67	+334.4	+168	+75.56	+395.6	+202	+94.44
+213.8	+101	+38.33	+275.0	+135	+57.22	+336.2	+169	+76.11	+397.4	+203	+95.00
+215.6	+102	+38.89	+276.8	+136	+57.78	+338.0	+170	+76.67	+399.2	+204	+95.56
+217.4	+103	+39.44	+278.6	+137	+58.33	+339.8	+171	+77.22	+401.0	+205	+96.11
+219.2	+104	+40.00	+280.4	+138	+58.89	+341.6	+172	+77.78	+402.8	+206	+96.67
+221.0	+105	+40.56	+282.2	+139	+59.44	+343.4	+173	+78.33	+404.6	+207	+97.22
+222.8	+106	+41.11	+284.0	+140	+60.00	+345.2	+174	+78.89	+406.4	+208	+97.78
+224.6	+107	+41.67	+285.8	+141	+60.56	+347.0	+175	+79.44	+408.2	+209	+98.33
+226.4	+108	+42.22	+287.6	+142	+61.11	+348.8	+176	+80.00	+410.0	+210	+98.89
+228.2	+109	+42.78	+289.4	+143	+61.67	+350.6	+177	+80.56	+411.8	+211	+99.44
+230.0	+110	+43.33	+291.2	+144	+62.22	+352.4	+178	+81.11	+413.6	+212	+100.00
+231.8	+111	+43.89	+293.0	+145	+62.78	+354.2	+179	+81.67	+415.4	+213	+100.56
+233.6	+112	+44.44	+294.8	+146	+63.33	+356.0	+180	+82.22	+417.2	+214	+101.11
+235.4	+113	+45.00	+296.6	+147	+63.89	+357.8	+181	+82.78	+419.0	+215	+101.67

APPENDIX V: LOGARITHMS AND ANTILOGARITHMS
FOUR-PLACE LOGARITHMS

N	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	3	5	8	10	13
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	5	7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	5
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	5
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	3	3	4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	3
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	2	3
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5

APPENDIX V: LOGARITHMS AND ANTILOGARITHMS

FOUR-PLACE ANTILOGARITHMS

Log	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	1	1	1	1
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	2	2
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	2	2
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	2	2
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	2	2
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	2	2
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	2	2
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	2	2
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	2	2
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	2	2
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	2	3
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	2	2	3
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	2	2	3
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	2	2	3
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	2	2	3
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	2	2	3
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	2	3	3
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	2	2	3
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	2	2	3
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	2	3	3
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	2	3
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	2	3
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	2	2	3
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	2	2	3
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	2	2	3
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	2	2	3
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	2	2	3
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	2	2	3
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	2	2	3
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	2	2	3
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	2	2	3
.43	2692	2698	2704	2710	2716	2723	2729	2735	2742	2748	1	1	2	3	3
.44	2754	2761	2767	2773	2780	2786	2793	2799	2805	2812	1	1	2	3	3
.45	2818	2825	2831	2838	2844	2851	2858	2864	2871	2877	1	1	2	3	3
.46	2884	2891	2897	2904	2911	2917	2924	2931	2938	2944	1	1	2	3	3
.47	2951	2958	2965	2972	2979	2985	2992	2999	3006	3013	1	1	2	3	3
.48	3020	3027	3034	3041	3048	3055	3062	3069	3076	3083	1	1	2	3	4
.49	3090	3097	3105	3112	3119	3126	3133	3141	3148	3155	1	1	2	3	4

Log	0	1	2	3	4	5	6	7	8	9	Proportional Parts 1	2	3	4	5
.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4
.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4
.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4
.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4
.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4
.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4
.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	3	3	4
.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	3	3	4
.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	3	4	4
.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	3	4	5
.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	3	4	5
.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	3	4	5
.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	3	4	5
.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	3	4	5
.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	3	4	5
.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	3	4	5
.66	4571	4581	4592	4603	4613	4624	4634	4645	4656	4667	1	2	3	4	5
.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	3	4	5
.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	3	4	6
.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	3	5	6
.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	4	5	6
.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	4	5	6
.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	4	5	6
.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	3	4	5	6
.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	3	4	5	6
.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	3	4	5	7
.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	3	4	5	7
.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	3	4	5	7
.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	3	4	5	7
.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	3	4	6	7
.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	3	4	6	7
.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	2	3	5	6	8
.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	2	3	5	6	8
.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	2	3	5	6	8
.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	2	3	5	6	8
.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	2	3	5	7	8
.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	2	3	5	7	8
.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	2	3	5	7	9
.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	2	4	5	7	9
.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	2	4	6	7	9
.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	2	4	6	7	9
.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	2	4	6	8	9
.92	8318	8337	8356	8375	8395	8414	8433	8453	8472	8492	2	4	6	8	10
.93	8511	8531	8551	8570	8590	8610	8630	8650	8670	8690	2	4	6	8	10
.94	8710	8730	8750	8770	8790	8810	8831	8851	8872	8892	2	4	6	8	10
.95	8913	8933	8954	8974	8995	9016	9036	9057	9078	9099	2	4	6	8	10
.96	9120	9141	9162	9183	9204	9226	9247	9268	9290	9311	2	4	6	8	11
.97	9333	9354	9376	9397	9419	9441	9462	9484	9506	9528	2	4	7	9	11
.98	9550	9572	9594	9616	9638	9661	9683	9705	9727	9750	2	4	7	9	11
.99	9772	9795	9817	9840	9863	9886	9908	9931	9954	9977	2	5	7	9	11

N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5
N	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5

APPENDIX VI: WORLD WEATHER EXTREMES

(Recorded Observations Only)

	Observation	Record
		Temperature
	Alaska	
1	Lowest recorded temperature	-78°F, Fort Yukon, January 14, 1934.
	United States	
2	Lowest recorded temperature	-66°F, at Riverside Ranger Station, Yellowstone Park, Wyo., Feb. 9, 1933.
3	Highest recorded temperature	134°F, Greenland Ranch, Death Valley, California, July 10, 1913.
	World	
4	Lowest recorded temperature	-90°F, Verkhoyansk, Siberia, February 5 and 7, 1892.
5	Highest recorded temperature	136°F, Azizia, Libyn, North Africa, September 13, 1922.
6	Lowest mean annual temperature	-14°F, Framheim, Antarctica[1].
7	Highest mean annual temperature	86°F, Masawa, Eritrea, Africa.
		Precipitation
	United States	
8	Average annual precipitation	29 inches, approximately.
9	Wettest State	Louisiana, 55.11 inches annual average rainfall
10	Driest State	Nevada, 8.81 inches annual average rainfall
11	Highest local annual average rainfall	150.73 inches, Wynoochee, Oxbow, Washington (based on 13-year record),
12	Greatest 24-hour rainfall	23.22 inches, New Smyrna, Florida, October 10-11, 1924.
13	Extreme min. annual average rainfall	1.35 inches, Greenland Ranch, California.
14	Extreme min. rainfall, 5 years	3.93 inches, Bagdad, California, 1909-1913.
15	Heavy snowfall record, 1 day	60.0 inches, Giant Forest, California.
	2 days	42.0 inches, Angola, New York.
	3 days	54.0 inches, The Dalles, Oregon.
	4 days	96.0 inches, Vanceboro, Maine.
19	Greatest seasonal snowfall	884.0 inches (73+ feet), Tamarack, California, winter of 1906-07.
20	Largest definitively recorded hailstone	1.5 pounds, Potter, Nebraska, July 6, 1928.
	World	
21	Greatest 24-hour rainfall	46.0 inches, Baguio, Luzon, Philippine Islands, July 14-15, 1911.
22	Greatest monthly rainfall	241.0 inches, Cherrapunji, India, August 1841.[2]
23	Greatest annual average rainfall	460.20 inches, Waialeale, Hawaii

1/ The estimated mean tamperature at the South Pole, elevation 8000 ft, is considerably below -220°C. 2/ 150 inches of rain fell in 5 consecutive days; the average annual in Cherrapunji is 426 inches.

APPENDIX VII.

THE GREEK ALPHABET

A	α - alpha
B	β - beta
Γ	γ - gamma
Δ	δ - delta
E	ε - epsilon
Z	ζ - zeta
H	η - eta
Θ	θ - theta
I	ι - iota
K	κ - kappa
Λ	λ - lambda
M	μ - mu
N	ν - nu
Ξ	ξ - xi
O	ο - omicron
Π	π - pi
P	ρ - rho
Σ	σ - sigma
T	τ - tau
Υ	υ - upsilon
Φ	φ - phi
X	χ - chi
Ψ	ψ - psi
Ω	ω - omega

INDEX

This section is comprised of two parts, a Contributor-Reviewer index and a Subject Index. On pages v - xxx there appears, in alphabetical order, a complete list of contributors and reviewers (not including advisers and members of the Panel of Appraisers), each with an accompanying reference number. In the table of contents each table title is followed, in parentheses, by the reference number(s) of the principal contributor(s) of that table. Single-source tables adapted directly from the literature have no such identifying numbers, but the literature citation is given in the headnote of that table. The Contributor-Reviewer Index lists, by number, all contributors and reviewers for each table. Table numbers are enclosed in "slashes," and are followed by appropriate reference numbers. For example, /1/ 211, 4036 indicates that Table 1, "Standard Solutions: pH_{20}" was contributed and/or reviewed by Roger G. Bates (number 211) and Claude E. ZoBell (number 4036).

In an attempt to provide as useful a subject index as possible, and at the same time to strive for maximum economy of space, certain expediencies have been employed. The Subject Index is designed for use in correlation with the table of contents, eliminating the necessity for most of the usual secondary index entries. Because each table title appears in the Contents, such correlation is relatively simple. For example, GLUCOSE is accompanied by many page numbers, among which are (random selection) 8, 17, 52, 233, and 250. The table of contents reveals the following: page 8, characteristics of glucose; 17, glucose as a component of glycosides; 52, glucose content of human blood; 233, glycolytic metabolism of glucose; 250, the role of glucose in photosynthesis.

Effort has been made to index scientific and common names for every organism and every chemical listed in the book. Unfortunately it has been impossible to adhere to any one standard system of nomenclature for either category--actually, "standard" systems themselves have undergone considerable change during the preparation of the Handbook. Consequently, it was decided that the nomenclature employed within the "text" of the book remain as in the data contributed by the many authorities and authenticated by other experts in the same fields. Wherever ambiguity appeared likely, entries were cross-referenced. Moreover, in most cases, synonyms (trade names, where applicable) and alternate designations accompany the nomenclature used within the tables.

Organisms are indexed down to the genus level. Obviously, a listing of all species would not only quadruple the size of the index, but also would be redundant because in the majority of cases the several species of a given genus are grouped together within any one table. Common names of organisms have been indexed, wherever possible, in two ways, e.g., there is an entry EVERGREEN(S) after which appear the numbers of all pages containing information on evergreens in general, in addition, each evergreen, e.g., PINE(S), SPRUCE(S), FIR(S), is also indexed. Again, in most tables all species of each tree are grouped in alphabetical order.

Indexing of table titles has been held to a minimum, and general subject headings appearing in the index apply to column headings or other sections of tables not directly indicated in the Contents.

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